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ABSTRACT

Utilizing nine schools located in the San Francisco Bay area, a study was conducted to examine the patterns by which microcomputers are accepted and implemented in high schools. Rather than the educational or social effects of this new academic resource, the study focused on: (1) the process of the behaviors and decisions leading to the acquisition of microcomputers, and (2) their subsequent implementation. Answers were sought to questions concerning what caused school administrators and teachers to become interested in educational microcomputers, what academic and administrative tasks are considered appropriate for microcomputers, what causes/enables the adoption of microcomputers, existing barriers to the adoption of microcomputers in schools, and the changes microcomputers bring to the schools that adopt them. Findings indicate that external pressures, rather than sound instructional practice, force educators to adopt microcomputers; school planning is usually insufficient to adapt microcomputers to the curriculum; introduction of the microcomputer produces a great deal of uncertainty and attendant anxiety in schools that adopt it; and, however "fragile" the microcomputer may be, it is probably not a fad that will pass away. Specific case studies of the diffusion of microcomputers in the nine schools, and summaries of site visits to each school, are appended. (JB)

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MICROCOMPUTERS IN THE SCHOOLS: A CASE OF DECENTRALIZED DIFFUSION

by
Everett M. Rogers, John McManus,
John D. Peters, and Joung-Im Kim

a report of the
INSTITUTE FOR COMMUNICATION RESEARCH
STANFORD UNIVERSITY

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Stanford and the Schools Project
and
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Stanford, CA 94305

April, 1985

No compulsory learning can remain in the soul... In teaching children, train them by a kind of game, and you will be able to see more clearly the natural bent of each.

Plato, The Republic, Book VII.

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EXECUTIVE SUMMARY

The present research describes and analyzes the process of adopting microcomputers and incorporating their use into the curricula of nine high schools located in the San Francisco Bay area. Unlike most research about new technologies, we were more interested in (1) the process of the behaviors and decisions leading to the acquisition of microcomputers, and (2) their subsequent implementation, than in the educational or social effects of this new academic resource. Our aim is to help educators who are considering bringing microcomputers into their schools to do so with a minimum of wasted effort and misspent dollars.

Principal Questions

We sought answers to the following research questions:

1. What causes school administrators and teachers to become interested in educational microcomputers?

2. What academic and administrative tasks are considered appropriate for microcomputers?

3. Are microcomputers just another educational fad like modular scheduling and language laboratories?

4. What causes/enables the adoption of microcomputers?

5. What are the barriers to adoption and diffusion of microcomputers in schools?

6. Once the first microcomputers are acquired, to what educational tasks are they put? How do their applications differ from the original plan for their use?

7. How do microcomputers and their courseware change the schools that use them?

8. What are the advantages and the drawbacks of decentralized diffusion of microcomputers in the schools?

Methodology

Our methodology is based on multiple case studies. These were built on a convergence of information provided from personal interviews with school administrators and faculty members over a two-year period. The case study approach was chosen because it permits analysis of a sequence of events occurring over time. Perhaps more importantly, the case study helps preserve the context of a complicated social process.

Findings

Our findings depict a creative, but often chaotic set of behaviors in the innovation process. The schools studied were blessed and beset by corporate gifts of computers, by students often more skilled than teachers in using microcomputers, by parents anxious about their children's access to an increasingly computerized world of work, and by financial scarcity that forced difficult decisions.

We learned that:

(1) About half of the schools studied acquired educational minicomputers and microcomputers largely due to external pressure from gifting corporations, parents, or students, not because educators decided that the new machines represented a better way

to present instruction.

(2) The usual level of school planning is insufficient to adapt microcomputers to the curriculum. The most successful cases occurred when microcomputer implementation was considered as part of a thorough re-examination of school goals, or at least where a committee of administrators, faculty, parents and students was convened specifically to oversee the innovation process for microcomputers.

(3) Although the computer may be introduced to a school through one innovative teacher, the principal and other administrators eventually must take responsibility for applying the new technology. Diffusion from one teacher to another is unlikely -- or at best uneven -- when the educational infrastructure either opposes to, or is apathetic to, the innovation.

(4) The educational microcomputer is still a "fragile" innovation, but it is probably not a fad that will pass from the school scene in a decade or two.

(5) None of the nine schools of study purchased more than a small fraction of their microcomputers from the regular budget.

(6) While corporate computer gift programs increase a recipient high school's use of microcomputers, such a donation is often a "Trojan Horse" in that the cost and time required to establish a computer center, obtain courseware, train teachers, and maintain the system may require substantial budget support.

(7) Given the rapid evolution of microcomputers and courseware, and the explosion of teaching applications--literally from arithmetic to zoology--instructional use of the computer has yet

to become routine in the high schools studied. Nor are applications likely to stabilize for several more years.

(8) The microcomputer introduces a great deal of uncertainty--and attendant anxiety--into the schools that adopt it.

(9) The computerized classroom envisioned by many educators, where each student works with a machine, is very distant from the day-to-day realities of the nine schools that we studied. Rather than devoting time and money to planning how students might learn more effectively, these high schools are preoccupied with survival in a climate of low confidence in public education and budgetary cutbacks.

MICROCOMPUTERS IN THE SCHOOLS: A CASE OF DECENTRALIZED DIFFUSION

by

Everett M. Rogers, John McManus, John D. Peters, and Joung-Im Kim [1]

INTRODUCTION

The present report examines the innovation process for microcomputers in nine high schools located in the San Francisco Bay area. Our purpose is to describe the patterns by which microcomputers are accepted and implemented in high schools. This report presents lessons learned from our analysis of the decentralized diffusion of educational computers.

Our report is divided into four parts. The first is a review of the literature of past educational innovations. The second part describes the context of the microcomputer innovation--schools in crisis. Our third part analyzes the process of innovation itself. The last section estimates the degree of implementation of microcomputers into academic practices in the nine high schools.

Studies of the implementation and impacts of microcomputers in schools are becoming because a whole generation of American children is beginning to grow up with computers, just as the children of the 1950s grew up with television. We are at a similar point in the history of microcomputers to that in which social scientists found themselves with television in 1961 when Schramm and others published Television in the Lives of Our

Children, the first compehensive look at the new medium's impact on American youth (Chen, 1984).

But microcomputers-- desktop computers connected to a video monitor and perhaps to a printer--may prove to be an even more fertile area of study because they promise much more than television. Television is predominantly a one-way medium of communication. What is special about microcomputers is their interactive capability. Children can carry on an instructional "conversation" with such machines, almost as they might with a human teacher.

The two-way capacity of the microcomputer makes possible a revolution in the classroom. As described by Papert (1980), Becker (1982), Bork (1984), and many others, students would receive individual "tutoring" from a microcomputer in the classroom of the future. Learners would move at their own pace, never exhausting the patience of their "videopal" on elementary lessons, nor reaching beyond its knowledge of advanced topics. They would become familiar at an early age with the logical algorithmic thinking of computer programming {2}. Human teachers, in these scenarios, would be freed from the routines of instruction and marking papers to help children with higher-order thinking and creativity.

It is important to study microcomputers in the classroom not just for their pedagogical potential, but because the workplace of the future is likely to revolve around such machines. Businessmen are applying microcomputers to tasks like word-processing, computer-assisted design, calculations,

projections, and record-keeping. The adoption of the microcomputer in the world of work, makes learning to use the new technology essential preparation for the "knowledge workers" (Porat, 1978) of tomorrow.

Aware of these new realities, U.S. schools are obtaining microcomputers at an accelerating rate. During 1983, nearly half of the secondary schools that had not previously owned microcomputers obtained at least one, according to a national survey (Becker, 1983). So by January of 1984, an estimated 53 percent of all schools -- 85 percent of all high schools -- in the United States had at least one microcomputer used for instruction.

Now, while we are still in the early stages of diffusion of microcomputers in schools, is the most rewarding time to study the process of adoption. An understanding of what causes a new idea to become accepted, and the process of its adoption leads to more intelligent control over social change. The fruits of that control are fewer instances of misdirected human energy and--especially for a costly innovation like microcomputers--wasted money.

Part 1

PAST RESEARCH ON EDUCATIONAL INNOVATIONS

Early research on the process of educational reform, well before the advent of the microcomputer in the latter half of the 1970s, provides a basis for understanding the innovation process in the school setting.

Schools, traditionally, have not been thought to be particularly innovative institutions. Consider C.P. Snow's anecdote:

> In a society like ours, academic patterns change more slowly than any others. I used to think that it would be about as hard to change, say, the Oxford and Cambridge scholarship examination as to conduct a major revolution. I now believe that I was over-optimistic (Snow, 1961).

More recently the view of schools as clinging to tradition has been challenged. Miles (1964) and particularly Havelock (1974) document an increasingly receptive attitude toward change in American schools.

In an overview of innovations in American education, Miles (1964) provided a set of helpful generalizations. First, he looked at the nature of educational systems. Diffusion rates for schools may be slower than those found in industrial, agricultural or medical systems, he argued, because of:

(1) The absence of precise scientific research concerning the advantages or disadvantages of an innovation; e.g., it might be proven that a new hybrid seed produces 10 percent more corn per acre, but the impact of modern math canot be so readily measured.

(2) The lack of change agents to push new ideas; e.g., seed salesmen or agricultural extension agents.

(3) The lack of economic incentives to adopt educational innovations. In contrast, a new manufacturing technology might cut production costs and thereby raise profits. Teachers and administrators are paid on the basis of their academic degree and longevity, not for their productivity.

Turning his attention to the innovation itself, Miles showed that:

(1) The more difficult the innovation is to master, the less likely it is to be adopted, other things being equal.

(2) Innovations which are perceived as threats to existing practices, rather than additions, are less likely to be accepted.

Lastly, Miles generalized about the internal political climate of the school undergoing innovation. He concluded that:

(1) Innovations are most likely to be adopted when they are promoted by someone (or a group) within the organization.

(2) Administrators are crucially important for introducing school innovations.

(3) Innovations have the best chance of acceptance when a new structure, perhaps an ad hoc committee, is appointed to implement them. Such a group can bypass hostile vested interests within the school.

(4) The longer the tenure of teachers and principals, the more stable their interaction and the more difficult it is to introduce an innovation.

In 1974, Havelock updated Miles' work on educational innovation with a national survey of school superintendents. Tracking successful innovations, Havelock found that the single most important factor affecting the adoption of new ideas, according to the superintendents, was the breadth of participation in planning and implementing the innovation among the faculty, administration, and staff of a school or district.

Microcomputers in Schools

A research literature about the diffusion of microcomputers in schools is just getting underway. Perhaps the most ambitious project is at the Center for Social Organization of Schools at Johns Hopkins University. Since 1982, Becker and his associates have conducted a series of national surveys among a representative sample of all schools, and later, among those reporting instructional use of microcomputers. Becker's (1982, 1983a, 1983b, 1984a, 1984b, and 1984c) principal findings include the following:

(1) The adoption of microcomputers is greatest in secondary education--85 percent or all high schools have at least one instructional computer versus only 42 percent of elementary schools. Also secondary schools are adding computers at a much greater rate than lower schools.

(2) Small parochial schools and public schools in poorer districts--particularly in the Southeastern U.S.--are least likely to have microcomputers.

(3) Schools serving impoverished minority students use their microcomputers more for drill-and-practice than schools serving white students and more affluent students generally. Schools serving non-minority students allot more time to programming with microcomputers than do those serving minority children.

(4) The impetus for obtaining microcomputers in the classroom is switching from an innovative teacher, or teachers, to administrators, as the innovation diffuses. At the same time, student access to microcomputers is increasing.

(5) Schools have relied on outside or special funding such as gifts and grants for about half of the microcomputers they have obtained. Grants for microcomputer purchases to less affluent schools have reduced the gap between their computer capability and that of more affluent schools.

(6) Dispersion of microcomputers throughout the school appears to have negative consequences for lower grade levels, who have less use and less impact. But multiple locations appear to have positive consequences for upper level schools, increasing utilization, equity of access, and breadth of applications.

Using a case study approach, Williams and Williams (1984) found that the most successful implementations of microcomputers reversed the commonplace sequence of buying hardware, then software, and then learning how to use the machine. They suggest that teacher training come first, followed by a decision about the best courseware to obtain, and lastly the purchase of machines most compatible with the software selected.

Sheingold and others (1983) looked at the diffusion of microcomputers in three school districts, one in New England, one in the Midwest, and one in the Southwest. They found a wide variety of applications and considerable uncertainty over the optimum uses of educational microcomputers. In two of the districts studied, the innovation process was decentralized, driven by individual teachers. While this pattern maximized the variety of applications, access to the machines was uneven. The third district's adoption was centralized, with microcomputers used specifically to upgrade the basic skills of below-grade

students. While this pattern led to efficient utilization of the computers, it limited their application, and might eventually stigmatize computer instruction as something for "dumb kids," the authors concluded.

Yin and White (1984) selected 12 school districts for case studies from a national list of 98 districts using microcomputers for special education purposes. The authors identified seven "practical guides" for effective implementation of microcomputers:

(1) Obtain microcomputers incrementally.

(2) Appoint a microcomputer coordinator.

(3) Formalize staff training.

(4) Involve both administrators and teachers in the innovation process.

(5) Get a few simple microcomputer applications working early.

(6) Mix administrative and instructional microcomputer applications.

(7) Create a microcomputer system in which all units are thought of as parts of a whole.

The Present Study

The present study differs from the research described above in three respects. First, the unit of analysis for our case studies is not the district, but the individual school --the crucible in which the innovation either takes or is rejected. Second, our study emphasizes a theoretical understanding of the

innovation process. We have matched the stages of microcomputer innovation in our case studies against models developed in earlier research on the diffusion of innovations in other fields. Third, we devote our analysis to decentralized diffusion, the most common process ror microcomputers in American schools, but the least investigated to date.

In some ways our schools of study face problems unique to the region and to California. The nine high schools, for example, suffered severe budget reductions imposed after 1978 when the state's voters chose to cut property taxes with Proposition 13. California has become the nation's ethnic/cultural melting pot and each of our schools of study has a minority enrollment (defined primarily as Asians, Blacks, Hispanics, American Indians, and Filipinos) of at least 20 percent. One high school reported only 3 percent white students. Many minority youngsters are literally just off the boat from Vietnam and other Southeast Asian nations, and have little or no command of English. Perhaps most importantly, given the topic of microcomputers, the majority of the schools studied are located in Silicon Valley, birthplace of the industry (Rogers and Larsen, 1984).

In most respects, however, the nine high schools of study are typical examples of American secondary education in metropolitan areas. Teachers are considered to be underpaid, class sizes are relatively large (and getting larger), drugs are misused by some students, and there are gaps in learning motivation and academic preparedness rerlecting divergent family economic and social backgrounds.

Part 2

SCHOOLS IN CRISIS

If the spate of national studies of American schools and schoolchildren are to be believed, then public education is in serious trouble. To quote just one of a series of recent nationwide reports critical of the schools, the authors of the President's National Commission on Excellence in Education (1984) wrote: "The educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a nation and a people."

Public education has been burdened by demands that schools become the integrating force in a society divided by race, ethnicity and family income. In addition, the schools are now the training place of handicapped children who until 20 years ago were treated privately or kept at home. We ask schools to supply able graduates to a world of work grown technologically so sophisticated that much of the knowledge learned by one generation is virtually obsolete in the next.

In major American cities, middle class families have abandoned public education to poor and minority students by moving to suburbs or by enrolling their children in private schools. Even though there are recent signs of state activity in revitalizing education budgets, financial support for public schools has been reduced from levels prevalent a decade ago. As a result, school programs such as guidance were dropped, classes were enlarged and younger teachers were laid off. The cyclic

process of declining performance, followed by allocation of fewer resources, leading to further declines, has led some educators to conclude that American schools are facing a time of severe crisis.

Reductions in School Funding

California schools have not escaped these broader trends in American education. Although the San Francisco Bay area is one of the nation's most affluent regions, in 1983 one of its largest school districts declared bankruptcy, shortened its school day, and dismissed hundreds of teachers. Indeed, teacher and staff layoffs were common everywhere after Proposition 13 became law in 1978, and have occured frequently since then.

Proposition 13 had very specific negative effects on the innovation of microcomputers in the nine high schools examined here. Financial retrenchment stripped the schools of younger teachers who were more likely to be computer literate than their older colleagues. And with bare bones budgets, there was little money for purchasing computers (hardware) or instructional programs (software), or for teacher training. Although Proposition 13 only affected California, the taxpayers' revolt ignited by the state's Jarvis-Gann Amendment spread across the country, bringing with it lean years for public education, particularly in urban areas.

Older Faculty

In the nine schools of study, the youngest faculty members

were the first to receive pink slips. Seniority was the principal criterion by which schools trimmed their payrolls. As a result the average age of teachers in several districts studied was above 50. Such older teachers are less likely than younger ones to have had computer training or experience in their own educational background. Additionally, older teachers are often set in their ways. Many were at first hostile to the computer because it represented change. Others reported fears that they would not be able to master the new machine and thus lose their students' respect.

One social studies teacher, for example, told us that he could not sleep during the week preceding a unit on "computer literacy" that he was required to teach. An older teacher, he had no experience with microcomputers and feared that he would look foolish in front of his students, some of whom had personal computers at home.

Teachers at another high school likened the classroom computer to such innovations as language laboratories, team teaching, and modular classes of the 1960s and 1970s, innovations that were introduced in their schools with high expectations, but later dismissed as fads.

One last result of a relatively older school faculty is an undercurrent of resentment among established teachers when they become the students of younger educators skilled in microcomputer use. In some cases, teachers learned from their students who were exposed to microcomputers at home or who has studied them in middle school.

No Regular Budget for Microcomputers

The scarcity of financial resources at the district and school level has had at least as strong an impact on the innovation process for microcomputers as the age of the faculty. In no school studied were regular budget items sufficient to equip a computer facility, purchase software, and train teachers. In fact, one nigh school sold or gave away its computer equipment in frustration over maintenance expenses (this school obtained other hardware a year later). Another high school sold its computers when the single teacher trained to use them retired. In a third school, five Atari 800s were collecting dust while school officials searched for appropriate and affordable instructional programs. And several schools were relying on the generosity of Silicon Valley computer engineers to maintain the school's hardware at no charge. There is no guarantee, however, that such services will continue indefinitely.

Corporate Microcomputer Gift Programs

Without funds to purchase microcomputers, several of the schools studied went begging at local computer companies. The resulting donations represent a potpourri of microcomputer and minicomputer hardware, much of it incompatible with machines the school already had, and more importantly, incompatible with courseware from other companies. At the very least, the mismatch of equipment required users to learn different protocols for each brand of equipment. Incompatibility is a hidden cost of computer

gifts to schools.

The dearth of funds to buy classroom computers forced schools to rely on grants from such sources as Federal Title I monies for remedial education--which must be directed at students from low-income families--Federal vocational education funds, the California School Improvement Program, and allocations that school districts set aside for innovative projects. Other solutions have ranged from seeking parental and community contributions through "Walks for Computers" and parent-teacher organization fund-raisers, to placing a video game arcade on the school campus as a magnet for students' spare change.

The problem with all but the last of these sources is that they are temporary, one-shot solutions to a growing educational expense. And the idea of providing video games at school as a revenue generator has proved to be more controversial than profitable. The uncertainty of resources hindered principals and teachers in planning the broad changes in curriculum that the computer offers. Lack of funds to buy microcomputers and software encourages short range planning, or planning in response to a donation of computers rather than originating months before the equipment arrives in the classroom.

A recent economic analysis of microcomputers in schools by Levin (1984, p.19) concludes: "For every dollar spent on hardware, some four or more dollars of other resources will be needed for the other resources required to provide instructional services such as supporting software, maintenance, personnel, and special facilities." While microcomputer hardware is the most

visible component of instructional computing, it accounts for a small portion of the total costs.

In sum, the lack of an adequate, stable source of funds for introducing the microcomputer to the classroom, has attenuated an administrator's most important asset--control.

Part 3

THE INNOVATION PROCESS

Rogers (1983) defines innovation as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption."

Perceived Characteristics of Innovations

The first step in an analysis of the innovation process for educational microcomputers is to examine this new idea in light of five attributes that are cardinal determinants of an innovation's rate of adoption (Rogers, 1983):

(1) Relative advantage is defined as "the degree to which an innovation is perceived as being better than the idea it supersedes." It can be measured in terms of economic or social gain, or in other ways. Evaluated for its potential, the microcomputer in the classroom promises a relative advantage over other educational techniques. It is cheaper than hiring a tutor for each student, it never tires of drill-and-practice, it keeps flawless individual records of progress, and it can be programmed at an appropriate level for each student. This pedagogical potential, however, has not been very fully realized. So the

relative advantage of computers in the classroom has yet to be decided except perhaps for some applications such as word-processing and, of course, the teaching of computer programming.

(2) Compatibility, a second attribute of innovations, is "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters." In concept, the microcomputer represents a break with education's past, since it is a mechanical "teacher." The research literature, however, does not show microcomputers supplanting faculty (see for example Sheingold and others, 1983), but instead as complementing them, indeed freeing them from many routine tasks. Teachers' aides are a more threatened population. As a machine designed to facilitate instruction, microcomputers represent another step in a tradition that began with the abacus and the blackboard, and progressed through the tape recorder and television monitor. The microcomputer proved to be generally compatible with educational values and needs among the nine high schools that we studied, but full implementation is not presently compatible with the limited financial resources of these school systems.

(3) Complexity, a third criterion, is "the degree to which an innovation is perceived as relatively difficult to understand and use." Unlike the first two attributes, complexity is negatively related to the rate of adoption. Unquestionably, the teachers that we interviewed believe that the computer is complex, and time-consuming to master.

(4) Trialability, a fourth attribute, is "the degree to which an innovation may be experimented with on a limited basis." This attribute is a positive characteristic of microcomputers that encourages rapid adoption. One machine, costing less than $500, can provide teachers and students with enough educational experience to judge its merit. The all-or-nothing quality of a mainframe or minicomputer contrasts with the more affordable trial of a microcomputer, especially the very low-cost model now available.

(5) Observability -- the last criterion, is "the degree to which the results of an innovation are visible to others." Within a school, students and teachers are likely to observe microcomputers, particularly if they are dispersed in classrooms throughout the school or in a computer laboratory accessible to all. Observability is dimished when microcomputers are placed in one or two classrooms open only to advanced students studying certain subjects, typically mathematics, science, or business.

In summary, the microcomputer has the advantages for rapid adoption of observability, trialability, and, to a lesser degree, compatibility. It has the disadvantage of complexity. The relative advantage of the microcomputer is still more promise than demonstrated performance.

Let us turn now to the process of innovation in the nine high schools. We will begin by decomposing the process into five sequential stages (see Figure 1) that characterize the innovation process within organizations (Rogers, 1983). The five-step model, which represents a synthesis of innovation process studies across

FIGURE 1. Stages in the Innovation Process in Organizations.

STAGE IN THE INNOVATION PROCESS	MAJOR ACTIVITIES AT EACH STATE IN THE INNOVATION PROCESS
I. Initiation:	All of the information-gathering, conceptualizing, and planning for the adoption of an innovation, leading up to the decision to adopt.
1. AGENDA-SETTING	General organizational problems, which may create a perceived need for an innovation, are defined; the environment is searched for innovations of potential value to the organization.
2. MATCHING	A problem from the organization's agenda is considered together with an innovation, and the fit between them is planned and designed.
---------- The Decision to Adopt ----------	
II. Implementation:	All of the events, actions, and decisions involved in putting an innovation into use.
3. REDEFINING/ RESTRUCTURING	(1) The innovation is modified and re-invented to fit the situation of the particular organization and its perceived problem, and (2) organizational structures directly relevant to the innovation are altered to accommodate the innovation.
4. CLARIFYING	The relationship between the innovation and the organization is defined more clearly as the innovation is put into full and regular use.
5. ROUTINIZING	The innovation eventually loses its separate identity and becomes an element in the organization's ongoing activities.

SOURCE: Rogers (1983)

many fields and in many different type of organizations, provides a useful heuristic for understanding the communication and decision-making of educators with respect to microcomputers in our nine schools of study.

The Five-Stage Innovation Process Model

The first two stages of the innovation model are together known as the initiation phase, which consist of all of the information gathering, conceptualizing, and planning for the adoption of an innovation, leading up to the decision to adopt.

(1) Agenda-setting: The first step in the initiation of an innovation occurs when general organizational problems, which may create a perceived need for an innovation, are defined, and the environment is searched for innovations of potential value to the organization. Agenda-setting is a continuous process in organizations. It can occur in two ways: [1] administrators can look within their organization to identify problems and to create solutions, or [2] leaders can seek answers outside their institution's boundaries.

Part of this on-going process of agenda-setting, therefore, is surveillance of the environment for new ideas that might benefit the organization. In fact, as March (1981) observed, administrators more often discover innovations by learning how similar organizations perform than from considering their own difficulties and creating solutions "in house." Awareness of the solution (the innovation) often precedes an acknowledgement of the problem.

In sum, although agenda-setting is intended to prioritize the problems of a particular organization, the agenda often is set through awareness of "outside" innovations by organization leaders. Thus innovations can create their own demand.

(2) Matching: It follows logically that if an innovation elsewhere shows promise of application within an organization, prudent administrators will match the innovation with their own problem to determine whether it fits their needs. Typical of such an assessment is creation of a mental scenario in which the innovation is vicariously adopted and administrators estimate its impact. At this point usually a decision is made whether to adopt, perhaps on a trial basis, or to reject.

The initiation phase ends when the decision is made to adopt the innovation. Implementation consists of all the events, actions, and decisions involved in putting an innovation into use.

(3) Redefining/Restructuring: The applications of a new idea often differ from the uses planned before adoption. During this stage, the first of the implementation phase, an adjustment process begins. If the fit between the problem and the innovation is good, then alterations in the innovation and the the organization are minimized. In many cases, however, some modification occurs. This process is "re-invention," the degree of change in an innovation as it is assimilated by an adopter (Rogers, 1983). Whether adopted as is, or re-invented, the innovation also causes modifications--which are sometimes profound--in the operation of the organization.

(4) Clarifying: As the innovation becomes integrated into the day-to-day operation of the organization, its uses and abuses become clearer to the members of the institution. The innovation is losing its newness and becoming embedded in established protocols. Through such clarification, the meaning of the innovation gradually becomes apparent as it is put into full-scale use.

(5) Routinizing: At this stage the innovation has been well-defined and becomes part of the infrastructure of the organization as the innovation loses its newness and is no longer recognized as a separate entity in the organization.

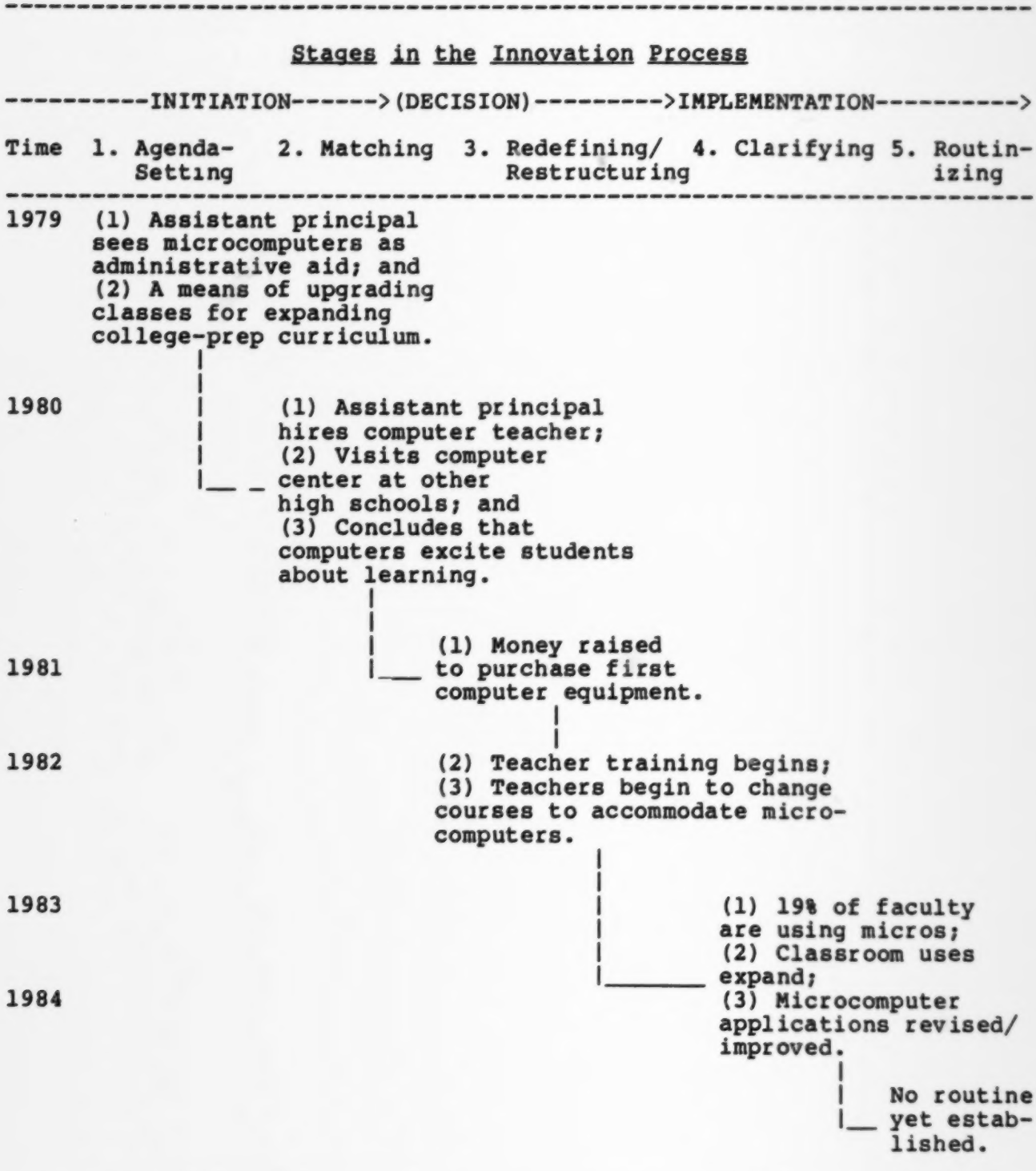
The innovation can be rejected at any of the five steps, even after it becomes part of the organization's routine (Havelock and others, 1974).

Figure 2 shows the five-step innovation process at Milpitas High School. Milpitas enrolls 1,700 students, 42 percent of whom are minority members (principally Hispanic and Black). The surrounding neighborhood is changing from blue-collar workers to white-collar Silicon Valley professionals.

The Five-Step Model of the Innovation Process Patterns in the Schools

The diffusion of microcomputers in the nine high schools of study is partly described by the innovation process model above, but also exhibits certain unique characteristics. The principal reason for this divergence is that the innovation process model

Figure 2. Classifying the Adoption of Microcomputers at Milpitas High School by Stages in the Innovation Process



schematized by Rogers (1983) is based on a synthesis of studies examining centralized (top-down) diffusion of innovations, rather than de-centralized diffusion such as has occurred mainly for microcomputers in the schools of study. Still, the innovation process model serves to illuminate the behavior under study, even if the order of the steps is sometimes rearranged or incomplete in the innovation processes that we investigated.

Initiation Phase

In four of the nine schools of study there was either a false start in adapting the computer to the classroom, or else there was little planning of how to integrate either minicomputers or microcomputers into the curriculum. In the other five high schools, the agenda-setting and matching stages occurred before the adoption decision (as expected by our model). These latter schools generally had a more successful experience with computers and are farther along in applying them to instructional tasks.

For those high schools with little planning, the machines arrived before educators could define their use. In such cases, typically, a computer corporation gave hardware to the school or parents and/or students demanded micros before local educators were prepared to offer instruction with the computer. Thus, pressures from outside of the school initiated the innovation process.

In one case, a special education student, acting on his own, persuaded a Silicon Valley company to donate several thousand

dollars' worth of computer equipment to his high school. School administrators put the gift in the library and a year later the school newspaper carried an article complaining that the computer remained idle and only the student who procured it knew how to use it. Neither administrators nor teachers took the time to integrate the computer into the functions of the library or to use it for other school tasks. In another school, the principal sent donated machines home for the summer with teachers to work out a way of incorporating microcomputers into the curriculum.

Such examples do not fit the innovation process model's stipulation that systematic information-gathering, conceptualizing, planning, and decision-making precede the adoption decision. The agenda-setting and matching stages appear rudimentary, or occur after-the-fact of adoption. In these cases the decision to adopt was made largely from outside, rather than a choice originating from within the organization after surveying the external environment. Adminstrators merely acquiesced to parental or community pressure, or accepted a gift of computer equipment.

On the other hand, in five of the nine schools, there was considerable mental effort expended before the hardware came to the school. Much of the thinking, however, was directed toward obtaining the machines, rather than toward how to use them.

The schools' planning efforts took one or more of several forms: Grant-writing for funds; soliciting parents and the community for money; visiting schools which had previously adopted computers; hiring a teacher experienced with computers

to coordinate the application of this new technology; and creating a committee of administrators, teachers, parents, and students to implement microcomputers.

In sum, about half of the schools fit the innovation process model at the initiation phase; the other half represent an after-the-fact reaction to the physical presence of computer equipment brought into the school by gift, parents, or by the determination of a teacher acting independently {3}.

Implementation Phase

Anotner difference between our findings and the innovation process model is the lack of a routinizing stage. Evidence of routinization would consist of stable, unchanged applications of microcomputers to the curriculum. But in every school of study the instructional uses of microcomputers were expanding rapidly. And with the exception of computer programming classes, all school uses of computers had a probationary character. As one school's computer pioneer told us: "I'm still skeptical. I don't know if these things [microcomputers] are going to be around in 10 years. I've seen a lot of things come and go."

One could argue that the absence of the final stage in the innovation process might be due more to the timing of our data-gathering interviews-- before our schools had developed routine uses for microcomputers--than to a different pattern of innovation. But a review of the literature on microcomputer implementation suggests that U.S. schools today are far from routinization. With the rapid development of succeeding

generations of newer, "smarter," and more affordable computers, their functions in schools may have to be redefined frequently to reflect the temporary nature of any present applications of microcomputers to education. In this sense, microcomputer routinization in schools will not occur until the next decade. Today it is an oxymoron to speak of "microcomputer rutinization," given the dynamic nature of hardware and software development.

Most of the nine schools of study can be located presently at the restructuring/redefining stage and/or at the clarification step. They have adopted microcomputers and are rapidly expanding as well in refining the new technology's applications. The role that microcomputers will eventually come to play in these schools is now being worked out.

The principal task of the restructuring/redefining stage is training teachers to change their pedagogical methods to include the capabilities of the microcomputer. Some cases of classroom restructuring at Mountain View High School are instructive:

1. Marilyn Baldauf, an English teacher, uses microcomputers as motivating and time-saving instruments both with her Gifted and Talented classes and her remedial students, one-third of whom are newly-arrived children from Southeast Asia.

Students with little academic interest are stimulated by using the word processing capability of the computer, she said. They become "very excited" when their stories are printed out. With the computer, she noted, students are "anxious to make corrections," an unusual inclination among adolescents.

Baldauf calls the new machines a "godsend" for students

speaking English as a second language. Software corrects spelling and grammar mistakes as well as drilling students in particular problems such as noun-verb agreement and capitalization. Lastly, she can reward students with educational computer games such as "Crossword Magic," and "Hangman."

2. Gary Bonnano teaches "basic skill development" for students who are falling behind their peers. These students--many of whom have short attention spans and little tolerance of frustration--enjoy the immediate results and instant reinforcement of microcomputers. The machines also reduce the "negative ego-stress" of being corrected by another human.

3. John Reisdorf teaches classes in woodworking, assisted by an Apple microcomputer, a disk drive, an Epson printer, and the Iowa Handbook of BASIC Computer Programs. The computer performs such tasks as calculating the total amount of wood needed for a student project and its cost.

In many of the nine high schools of study, the redefinition/restructuring stage coexists with the clarification stage. Redefinition continues--especially for teachers who are just undergoing computer training or have just adopted--while those who have decided to use the computer upgrade their skills or perhaps write more appropriate instructional programs.

Microcomputers: Another Educational Fad?

Even if microcomputers have not jet been very integrated into secondary education, we can ask whether they are here to stay or are just a fad. The enthusiasm of teachers and students who use

microcomputers argues for their permanence. So does the general willingness of the California and U.S. Department of Education to allocate grant money for the purchase of computer hardware and software. Popular acceptance of computers both at home and in the workplace also indicates their stability. With computers in 1984 being the second most-advertised item on television (next to food products) and commanding the front page of such news media as Time Magazine, the image of the microcomputer as a valuable and essential part of the future is receiving powerful support.

Perhaps most telling are the arguments made by thinkers such as Daniel Bell (1973) and Mark Porat (1978) about what they call the "information society." In such a society the majority of jobs involve the manipulation of information. Unquestionably, computers with their associated data-banks and networks are the evolving means of information storage and retrieval. When coupled with cable television and satellites, computers also become part of the mechanism of information transmission. If this is where the jobs are, then education cannot afford to be elsewhere.

The case for computers as an educational innovation that will "stick" is far from airtight, however. Neither Federal nor state governments have encouraged schools to adopt microcomputers by earmarking public funds for their purchase and implementation. As a consequence, by 1984 only a fraction of high school students had access to a microcomputer either in school or at home (Becker, 1984a).

Like a new strain of seed, the innovation has sprouted, but

has yet to prove it can flourish against competition. Early enthusiasm for an innovation has proved to be no guarantee of ultimate acceptance. Schools that spent tens of thousands of dollars on language laboratories in the 1960's, for example, demonstrate the wisdom of withholding judgement until the novelty has worn off of an innovation. It is also important to note that adoption of computers in our schools of study typically was the work of one, or at best, a small group of interested teachers and/or administrators. With their transfer or retirement or their abandonment of education for more lucrative jobs in high-technology industries, the innovation's use in a school could wither. Microcomputers in a school are a fragile innovation. Perhaps most importantly, few schools have committed their regular budget dollars to computers. Thus they have no investment to defend.

Finally, exactly what computer-related occupations schools train students for may be quite different from the actual jobs that are expected to exist. Relatively few individuals will be computer programmers ten years from now (the estimated number is predicted to decrease from about 200,000 today to only 100,000), although all but one of our nine high schools of study taught classes in computer programming. Most individuals in 1995 will use computers as a tool for accomplishing certain tasks. They need to be trained today, as high school students, in microcomputers, but they need to know how to apply a computer to writing, accounting, and other occupational tasks. This general knowledge of computer uses is sometimes called "computer

literacy." Today's high school students do not need to be trained as computer programmers. Our high schools of study emphasize programming, and this is one reason for the vulnerability of microcomputers in education.

Centralized and Decentralized Diffusion

As mentioned earlier, the primary reason that the previous model of the innovation process failed to describe some major characterisitcs of what we encountered in the nine high schools, is that the theoretical typology is more suited to a centralized type of diffusion than to the grass roots spread of microcomputers in schools that we encountered.

In the classic diffusion model, overall control of diffusion decisions (such as which innovations to disseminate, how to go about it, and to whom to offer the innovation) are made at the top of a hierarchy and then passed down. In centralized diffusion, adoption of the innovation spreads in a one-way direction from experts to users. The process is vertical (see the direction of arrows in Figure 1). Decentralized diffusion, however, has a more horizontal orientation with shared authority and control among members of the organization. For example, one teacher may find that computers are essential to instruction in a particular class and find a way to obtain one; another instructor may choose not to use them. A convergence model of communication {4} in which participants create and share information as they strive for mutual understanding (Rogers and Kincaid, 1981), better explains patterns of interaction in decentralized diffusion than does a linear communication model with a

designated sender and receiver. Decentralized diffusion also demonstrates a greater degree of re-invention, or modification of the innovation by the user, than does centralized diffusion. But decentralized diffusion may also be more chaotic and squander scarce resources. Table 1 contrasts centralized and decentralized diffusion systems.

Because decentralized diffusion assumes the user is competent to make implementation decisions, it is most appropriate when (1) the users are highly educated and technically competent; and (2) when the innovation is not very abstract or technologically complex (Rogers, 1983). In general, the teachers encountered in our nine Bay Area nigh schools were highly educated. Many, if not most, had Master's degrees. But they did not evidence a high level of technical competence about computers. Microcomputers are without question technologically complex (even if conceptually simple).

The grass-roots spread of microcomputers in the high schools studied has been plagued by false starts, a lack of planning and coordination, and highly uneven access to computers between schools and even between students at the same school {5}.

Perhaps it is now time for the Federal government, state departments of education, and the local school districts to bring the advantages of centralized development to bear on the future implementation of computers in instructional settings. Perhaps the decentralized approach has been appropriate in acquainting educators with the new technology, in fostering wide experimentation with its application, and in tailoring programs

TABLE 1. Characteristics of Centralized and Decentralized Diffusion Systems.

Characteristics of Diffusion Systems	Centralized Diffusion Systems	Decentralized Diffusion Systems
1. The degree of centralization in decision making and power.	Overall control of decisions by national government administrators and technical subject matter experts.	Wide sharing of power and control among the members of the diffusion system; client control by local community officials/leaders.
2. Direction of diffusion.	Top-down diffusion from experts to local users of innovations.	Peer diffusion of innovations through horizontal networks.
3. Sources of innovations.	Innovations come from formal R&D conducted by technical experts.	Innovations come from local experimentation by nonexperts, who are often users.
4. Who decides which innovation to diffuse?	Decisions about which innovations should be diffused are made by top administrators and technical subject-matter experts.	Local units decide which innovations should diffuse on the basis of their informal evaluations of the innovations.
5. How important are clients' needs in driving the diffusion process?	An innovation-centered approach; technology-push, emphasizing needs created by the availability of the innovation.	A problem-centered approach; technology-pull, created by locally perceived needs and problems.
6. Amount of re-invention?	A low degree of local adaptation and re-invention of the innovations as they diffuse among adopters.	A high degree of local adaptation and re-invention of the innovations as they diffuse among adopters.

SOURCE: Rogers (1983, p. 335)

to the needs of individual schools. But now it may be best to create a higher degree of standardization and centralization in microcomputer diffusion, both for reasons of efficient management of scarce resources and to achieve greater equity of access to the benefits of microcomputers in schools.

Important Actors in the Innovation Process

Innovation is a keenly social process, so it is important to examine the key roles that govern whether adoption takes place, and when it does, the speed and adequacy of implementation.

We identified six important roles that guided the adoption of computers in the nine high schools studied:

1. The computer champion -- typically a teacher of mathematics, business, or science, who saw the usefulness of computers in instruction before others in the high school. This individual -- and it was usually one person at the start of the innovation process -- finds a way to permit student access to a computer. Similar to the "computer buff" of Sheingold and others (1983), the champion begins the diffusion of computers through conversations with other teachers and administrators as well as demonstrations of computer applications to instruction. The computer champion may be a present member of the faculty or someone hired specifically for his or her computer expertise.

The computer champion often does not remain at one high school, or at least does not stay in his or her previous full-time instructional capacity. In two of the nine schools studied, the computer champion was tapped by the school district for administrative work in diffusing computers throughout the

school system. In another school, the early champion left for a university job. And in other cases, the champion began writing instructional software in what became a transition out of the classroom into being a self-employed entrepreneur.

In many respects the computer champion fits the role of the innovator in past diffusion studies. He or she may be considered a little odd by most co-workers and is likely to have a circle of friends that reaches beyond fellow teachers in the local school. As Rogers (1983) points out, the innovator must be a risk-taker, one who has rated his or her own efficacy highly. Such high self-efficacy is not the norm among teachers.

The behavior of two computer champions in our schools of study illustrate the characteristics and influence of this "spearhead" role in fostering innovation. The two are Virginia Kurzweil, former business teacher at Los Altos High School in Los Altos, and Roger Selsback, head of the business department at Capuchino High School in San Bruno.

Mrs. Kurzweil had contacts in the computer industry through her husband who was an electrical engineer at IBM. She saw in the mid-1960s that computers were profoundly changing American business. Acting independently, she taught her business classes about the symbolic languages of the mainframe IBM 1401 computer. Four years later, in 1971, she was able to persuade the Mountain View-Los Altos School District to let her students receive their first "hands on" experience with a computer, a NCR Century 100, located at the District office. Because the computer was dedicated to administrative tasks during school hours, Mrs.

Kurzweil and her husband conducted sessions on Friday night and into Saturday morning at the school district office with interested students. By wrangling with the Los Altos High School administration, gradually Mrs. Kurzweil was able to offer students a four-year computer curriculum using a donated DEC PDP-8 computer.

But Mrs. Kurzweil's adoption of computers did not spread to other teachers at Los Altos High School. Nor did enrollment in her classes demand that more teachers be assigned to teach with the computer. Certain of her colleagues described her as "not a team player." When she took another job in 1981, most of her computer equipment was sold and her innovation withered at Los Altos High School.

Roger Selsback, the computer champion at Capuchino High School, on the other hand, became the center of a teacher-to-teacher diffusion of classroom computer applications. Rather than operating on his own, as did Mrs. Kurzweil, Selsback enjoyed the enthusiastic support of Principal Sam Johnson (who eventually became interested enough in microcomputers to buy one for his home). Teaming with the principal, Selsback was able to put the reward structure of the school's administration behind the diffusion of microcomputers. Selsback further broadened his base of support by offering instruction in microcomputers to other teachers and parents at such events as computer summer camps. He now gives workshops on microcomputers at others schools as a statewide educational consultant.

Both Los Altos and Capuchino High Schools have integrated

computers into their program of study. But Los Altos' early lead in adoption was eclipsed by Capuchino, partly due to the characteristics of their respective computer champions.

2. A second key actor in microcomputer diffusion is the principal. A clear pattern emerged from our study: If the computer champion were the principal or were allied with the principal, the spread of microcomputers for instruction in a high school was markedly faster and more coordinated than when the champion was a teacher working alone.

Although we found no principals who said they were hostile to instructional computing, their enthusiasm for computers and their familiarity with them was a major determinant of the degree to which micros were integrated into a high school curriculum. An obvious reason for this pattern is the principal's ability to direct budget and personnel toward microcomputer applications {6}.

One example may serve to demonstrate the amount of influence on the innovation process wielded by the principal. In 1980, when Robert Palazzi came to Aragon High School in San Mateo as its principal, he encountered an outright rejection of computers as an educational resource. The previous principal had sold or given away all but one TRS-80 microcomputer in frustration over unaffordable maintenance costs. Most teachers at Aragon were hostile or indifferent to educational computers.

Playing upon support for using microcomputers in the classroom from students and parents, Palazzi soon formed a computer committee, chaired by the director of the social studies

department, to plan microcomputer applications at Aragon. The principal put his stamp on the committee in three ways. First, he steered it toward creating a requirement that all students take a "computer awareness" module in their freshman year--unique among our nine schools of study. The breadth of the mandate also put pressure on many teachers to familiarize themselves with microcomputers. Second, when the school faculty could not decide whether to purchase Apple or TRS computers, Palazzi authorized two computer centers, each equipped with its own brand. The dialogue created between the two sides, he argues, is "very healthy and rare in the schools." Third, Palazzi persuaded the committee not to offer classes in computer programming at Aragon--also unique among the nine schools we studied. The principal wanted to avoid concentrating Aragon's 18 microcomputers in any one discipline, and he was not convinced that computer programming was the way to go.

As principal, Palazzi also was able to influence how a State of California "Local Staff Development Program" grant was spent. He put some of the money in a fund to purchase microcomputers and directed much of it to paying teachers to learn to use the new technology.

Under Palazzi's guidance, the microcomputer has become an innovation affecting every incoming student at Aragon High School through its computer literacy course. No other school of study can make that claim.

3. The third key role in microcomputer diffusion is played by the parents of schoolchildren. Through direct contact with

teachers and administrators, as well as more formal intercourse in parent-teacher organizations, parents influence a school's directions regarding microcomputers. With the increasing diffusion of home microcomputers-- an estimated 24 million Americans owned micros by 1984, up 7 million from the year before (Channels of Communications, 1984) --parents are beginning to have a very direct stake in this new technology. One popular reason for purchasing a home computer is to provide an educational asset for children. These parents, often joined by their youngsters who have become adept at using microcomputers, form a unified lobby which schools cannot ignore.

In our study, parents and members of the community the school served also were an important source of funds to purchase computers. George Washington High School in San Francisco staged a highly successful "Walk for Computers." In San Jose, at Willow Glen High School, parents contributed rummage for a school-wide garage sale whose proceeds were to be used for equipment purchases. Unfortunately, the publicity the high school generated about the sale attracted thieves who carted away the sale items in a truck. The story has a happy ending, however. Apple Computer Corporation of nearby Cupertino read about the theft in a local newspaper and donated the computer that the school had hoped to buy.

4. The fourth actor in microcomputer diffusion is the computer industry. As noted earlier, schools located in and near Silicon Valley have a special relationship with the microelectronics companies that grew from the industry begun in

the Stanford Industrial Park two decades ago. Most computer companies now have gift programs for schools that are national in scope. Led by Apple's innovative offer in 1982 to donate a computer to every school in America--103,000 in all-- in return for a special tax break, computer companies are eager to provide price discounts to get their computers into schools {7}.

The industry's generosity is not without purpose. Computer manufacturers have learned that brand loyalty transfers from the school to the home or corporate purchase, or to the next school purchase. Donated machines also represent corporate tax write-offs.

Schools have found that "free" computers actually can be quite expensive. Software and peripherals such as printers and disk drives must be purchased before schools can fully operate their systems. A gift computer can become a "Trojan Horse" for a high school after totaling the time and cost of setting up a computer center, training teachers, maintaining the system, and updating courseware. One donated computer required about $300 per month in preventive maintenance. "One more gift like that," a district administrator quipped, "and we'll go under."

5. The fifth major role is played by <u>educational funding sources</u> such as the school district, the state department of education, or the U.S. Department of Education. In the present study these sources usually were approached through one-time grant applications, rather than as sources of stable funding over long periods. Typically the money--regardless of the level at which the grant was allocated--was not earmarked for

microcomputers but for more generic purposes such as vocational education or as part of a school improvement plan. Besides their temporary nature, most of the grants had strings attached requiring that equipment bought with the money be used only for certain purposes, such as for remedial education, or in industrial arts classes, or that it be reserved for a certain group of students (usually the socioeconomically disadvantaged).

6. The last major actor in the diffusion of microcomputers is the student, the ultimate focus of the other five roles. In many schools, students were very important lobbyists for microcomputer purchases. In a few cases, students turned the tables on their teachers by helping them understand how to use microcomputers.

One computer champion, William "Sandy" Wagner, who became instructional computer coordinator for the Santa Clara County Office of Education, owes his new job to students who "drafted" him to learn about computers when he was a teacher at Los Altos High School. Pressure from students is normally associated with parent lobbying since the students most likely to demand computing classwork are those with access to machines at home.

In any particular high school some, all, or none of the roles described above may be involved in the initiation and implementation phases of the innovation processes. Likewise one or more may dominate the others. The particular pattern has clear implications for how the school integrates computers into its ongoing operations.

Part 4

DEGREE OF MICROCOMPUTER IMPLEMENTATION

Before 1982 there were fewer than a score of microcomputers among the nine high schools studied. Most of these were used for administrative tasks such as keeping students' grades and maintaining attendance and other administrative records. What computer instruction occurred was carried out on terminals attached to a computer elsewhere or by traveling to a computer facility at a university or other computing center. The number of students involved in such classes seldom included more than 1 percent of total enrollment among the high schools of study. Very few teachers had used a computer in any capacity.

By 1984, the same schools reported upwards of 225 microcomputers--a tenrold increase in two years. Five of the nine schools studied have already made plans to add 67 more microcomputers in 1985.

Microcomputer Applications

A list of the most common present applications of computers includes, in addition to administrative uses:

(1) Computer programming (most schools use BASIC, a few have introduced PASCAL) {8}.

(2) Mathematics, including trigonometry, geometry, algebra and calculus.

(3) Foreign languages.

(4) English composition.

(5) Accounting.

(6) Word processing/data processing/business skills.

(7) Career decision-making.

(8) Special education.

(9) Drill-and-practice in remedial education, particularly mathematics and English.

(10) Electronics

Less common applications among the nine schools of study include:

(1) History/civics/world studies.

(2) Biology/zoology.

(3) Physics.

(4) Scholastic Aptitude Test (SAT) preparation.

(5) Drafting in industrial arts.

(6) Statistics.

(7) Speed reading.

(8) Journalism/layout.

(9) Spelling.

(10) Video games.

As suggested by this list of 20 applications, since 1982 the student use of computers also has risen sharply. Classroom microcomputer applications are growing fast enough that between 15 and 25 percent of the student body in the nine schools of study is presently exposed to the new machines. Such a rapid expansion from 1982 to 1984 suggests that Aragon High School, where all students take at least one class using microcomputers, represents the future several years hence in the other eight schools of study.

Growth of Teacher Familiarity with Microcomputers

The number of teachers who could be considered expert or even intermediate in their command of computers and programming skills remains very small, as few as one or two per school on the average (the nine schools of study each have from about 50 to 80 teachers). But the number of teachers who have beginning skill levels--often adequate to teach simple applications of computers such as word processing--grew dramatically between 1982 and 1984. One- to five-day workshops sponsored by the school district, summer courses, introductory classes offered by computer retailers (Radio Shack), and private study (often accompanying purchase of a personal computer for the home) have driven this surge of computer knowledge. Because of this decentralized learning process, exact figures are not available for the number of teachers who are presently available. Estimates of elementary "computer literacy" among teachers in the study schools range from 10 to 50 percent of the total faculty.

These two-tiered findings -- a very small number of teachers with strong computer skills and a moderate number with only a basic familiarity with microcomputers -- is the direct result of budget constraints, and to a lesser extent, of decentralized diffusion. Since funding for microcomputer applications, including teacher training, is outside the normal school budget in the arena of one-time grants and donations, schools have not been able to pay for intensive university-level training of faculty in this new technology. Likewise, with decentralized

diffusion there is no superior authority to insist that teachers acquire a certain level of expertise.

Infrastructural Barriers to Microcomputer Diffusion

As a result of these financial restrictions, the greatest hurdle to the diffusion of microcomputers in the classroom is likely not to be the potential adopter's attitude toward the innovation--normally the deciding factor--but restrictions imposed by the schools' infrastructure. The normal spread of an innovation from person to similar person has been hampered by the lack of a reward structure encouraging adoption. Teachers seeking an in-depth knowledge of computing have usually had to learn on their own. Typically, a selected teacher may have his or her course load reduced by one class per day. Money to pay tuition for courses at local universities as often comes out of the teacher's pocket as from the school budget.

For the rate of adoption of microcomputers in our high schools of study to "take off" in the next few years, so as to reach an adoption level of 50 percent, considerable additional resources would be needed. Certain teachers would need a year or more of release time from regular teaching duties to create appropriate microcomputer software and to integrate such instructional materials into their courses. Many such teachers would need to collaborate with computer programmers, instructional designers, and subject matter specialists in order to create the needed software. Funding and other resources for such a large-scale effort are certainly not presently available

in the nine California high schools of study. This lack represents the major infrastructural barrier to further adoption of microcomputers in these schools. Figure 3 illustrates the nature of these infrastructural barrier to effective diffusion of microcomputers in high schools. Without a major "push" toward creating appropriate, easy-to-use software, followed by a massive training program for teachers, the S-curve of microcomputer adoption will not take off.

Given these kinds of institutional restrictions, the grass-roots spread of microcomputers in the schools has been remarkable during the past two years. But it is still a long way from the computer-aided classrooms envisioned by futurists where each child interacts with his own electronic "video pal" (Becker, 1982). Since the microcomputer is primarily utlized one-on-one, it is important to realize that even with the increase in microcomputers planned for the 1984-85 year among the nine study schools, there will still only be one machine for every 60 students.

SUMMARY AND CONCLUSIONS

The literature on microcomputer diffusion in schools indicates that the process is more often decentralized than centralized. Spread of the microcomputer innovation has not been organized at the Federal level, nor, in most localities, at the state level or the school district level. In fact, in about half of our schools of study the innovation process has not been very centralized even at the local school level. This finding is a key

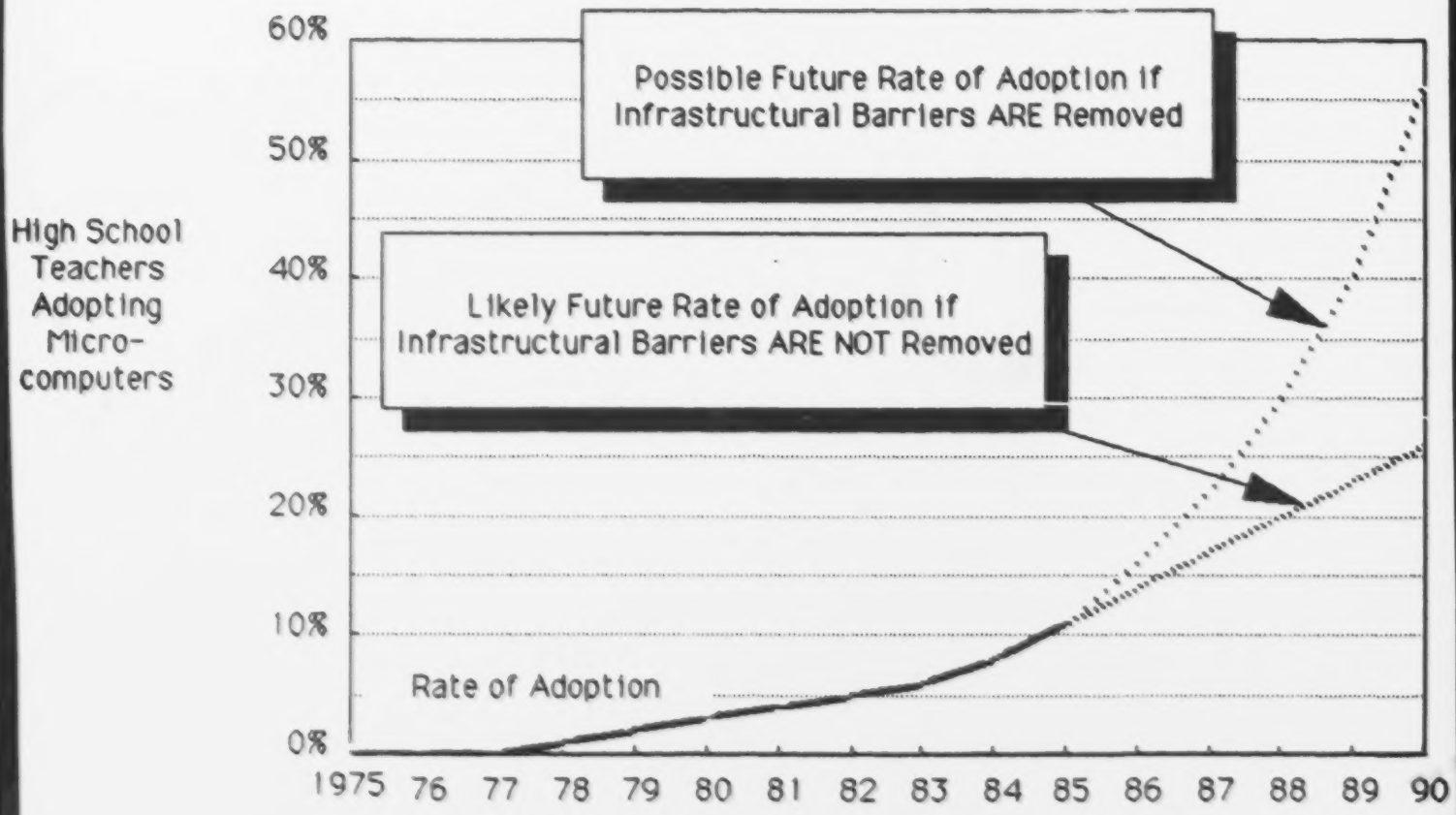

High School Teachers Adopting Micro-computers
60%
50%
40%
30%
20%
10%
0%
Possible Future Rate of Adoption if Infrastructural Barriers ARE Removed
Likely Future Rate of Adoption if Infrastructural Barriers ARE NOT Removed
Rate of Adoption
1975 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90

FIGURE 3. Likely, and Possible, Future Rates of Adoption for Microcomputers in High Schools, Depending on Infrastructural Barriers.

to understanding how the innovation process works.

The decentralized innovation process allows maximum latitude for individual creativeness among teachers and administrators as they adopt an innovation. The horizontal direction of communication and authority-sharing permits many useful applications of microcomputers to flourish and it encourages the abandonment of unsuccessful microcomputer uses in the classroom.

On the other hand, when the diffusion process is decentralized, gaps can form between adopters and non-adopters. Students cannot expect to have equal access to microcomputers. Without the directed efficiency of a hierarchical communication network, word of the best applications of microcomputers is likely to spread slowly. There are also false starts and instances of "re-invention of the wheel."

The following generalizations are offered as lessons learned from the innovation experience with microcomputers of our nine schools of study.

(1) Although several high school computer programs have roots going back 10 or 15 years to mainframe computers, most of the implementation of computers in classwork has occurred since 1982 with the increasingly rapid diffusion of microcomputers.

(2) About half of the schools that we studied acquired educational minicomputers and microcomputers largely due to external pressure from gifting corporations, parents and students, not because educators decided that the new machines represented a superior means of instruction.

Where planning for microcomputers occurred, often as much

effort was spent by school staff in obtaining computer hardware as in planning its ultimate educational uses. Many high school teachers and administrators want microcomputers without knowing precisely why.

The upswing in purchases of home computers, the concentration of media advertising on acquiring a microcomputer (or falling behind the competition), and the explosion of microcomputer applications in the workplace are creating enormous community pressures on schools to adopt this innovation immediately. Wise educators soberly plan classroom applications and select courseware before leaping into a major purchase--or even courting a corporate donation--of microcomputer equipment.

(3) The usual level of planning is insufficient to adapt microcomputers to a school's curriculum.

The most successfully diffused innovations occurred where microcomputer implementation was considered as part of a thorough re-examination of school goals, or at least where a committee of administrators, faculty, parents and students was convened specifically to oversee the innovation process. In our schools of study microcomputers are not just another instructional innovation like a language laboratory or a curricular innovation like Modern Math. Each of these ideas affected just one area of school study and one group of teachers. In contrast, microcomputers are used across the curriculum in our schools of study, and their classroom potential is just beginning to be explored. The adoption of microcomputers should cause a re-thinking of what to teach and how to teach it.

(4) The innovation process for microcomputers in a high school is usually spearheaded by an innovation champion, one teacher (often in math, science, or business) who obtains computer equipment, seeks to gain the support of school administrators, often helps fellow teachers learn to use computing, and may develop software.

(5) Although the computer may be introduced to a school through one innovative teacher, the principal and other administrators eventually must take responsibility for applying the new technology.

Diffusion from one teacher to another is unlikely -- or at best uneven -- when the educational infrastructure either opposes or is apathetic to the innovation. In high schools where the principal was involved early in the innovation process, applications of microcomputers have reached across more disciplines and involved more students than in cases where diffusion occurred from a teacher computer champion to other teachers.

The involvement of the principal is important because only he or she is usually able to manipulate incentives and disincentives to facilitate the adoption of innovations like microcomputers. It follows that the principal who involves as many of the faculty, the parents, and the students as possible in support of the innovation stands the greatest chance of rapid and widespread adoption. In general, the more individuals, particularly among the faculty, who are involved, and the greater the intensity of their committment to computer implementation,

the more satisfactory will be the intergration of microcomputers into the school's instructional program.

The current limits for microcomputer diffusion in high schools appear to be more infrastructural than attitudinal, more a matter of organizational structure and available resources than of individual teacher willingess to adopt (although some computerphobia exists, especially on the part of older teachers).

(6) Due to limited financial incentives and the age of the school faculty, there is typically only a small core of two to five teachers and administrators in each of the high schools of study that are excited about, and competent in using microcomputers.

(7) The adoption of microcomputers in the high schools of study is fragile in that only a few teachers have much knowledge about computers and the regular school budget was usually not involved in obtaining them.

But microcomputers are unlikely to be a passing fad because of the depth of their penetration into the world of work, and due to their considerable potential as teaching devices.

(8) While corporate computer gift programs increase a high school's use of microcomputers, such a donation is often a "Trojan Horse" in that the cost and time required for setting up a computer center, obtaining courseware, training teachers, and maintaining the system, requires considerable continuing budgetary support.

(9) With a dedicated facility, individual responsibilities, continuing costs, and, eventually, a line item in the school

budget, launching a computer center in a high school represents an important change in the school's organizational structure.

(10) Students taking certain courses, particularly mathematics and business, enjoyed above-average access to a school's microcomputers since the computer champion was most likely to teach these subjects.

Becker and others (1984b) found that superior students gained more access to microcomputers than below-average pupils when implementation was decentralized within the school, i.e., when one or more teachers independently procured computers for classroom instruction. Where diffusion was coordinated by the school principal or a designated committee of teachers, students whose ability was average or below were more likely to have access to computers equal to the best pupils. A similar pattern obtained in our study of nine high schools.

(11) Given the rapid and continuing evolution of microcomputers and courseware, and the explosion of teaching applications--literally from arithmetic to zoology--instructional use of the microcomputer has yet to become routinized in the high schools studied.

Nor are applications likely to stabilize for at least several more years. The academic applications of microcomputers, the machines themselves, and the courseware are in a state of rapid evolution. Far from becoming routine themselves, microcomputer applications are challenging the routines of American schooling.

(12) Microcomputers are adopted simultaneously in high

schools [1] for administrative purposes like record-keeping, which usually go well, and [2] for instructional purposes, which do not go so well.

(13) The microcomputer introduces a great deal of uncertainty -- and attendant anxiety -- into schools that adopt this technology.

Many teachers in our high schools of study fear (or feared) that they would not be able to master the microcomputer. Administrators are still searching for ideal locations tnat maximize student exposure to a relatively few machines. And funding for microcomputers remains a major question mark.

(14) The computerized classroom envisioned by certain educators (where each student works with a machine) is very distant from the day-to-day realities of the schools that we studied, schools that are preoccupied with survival in a climate of public criticism and financial crisis.

The diffusion of microcomputers in the nine high schools of study comes at a time when many educators are demoralized by their diminishing numbers and social status, and the public is skeptical about school effectiveness.

Even with a substantial decline in the price of microcomputer hardware and appropriate software--whose cost is likely to depreciate more slowly--the capital burden of providing one machine per student is difficult if not impossible to surmount in the present political atmosphere for schooling. The purchase of microcomputers is not the only economic hurdle. Given the high level of activity of many youngsters and the

fragility of some microcomputers, a sizeable maintenance and replacement budget would also be required for a high school to achieve an effective program of microcomputer use.

Perhaps microcomputers will help instill renewed public excitement and confidence in public schooling sufficient to pay for a future "golden age" of education where each child has an electronic tutor patiently and individually pacing instruction, and where teachers are freed of the drudgery of their profession to inspire and shape young minds. That visionary potential is far from being achieved in our nine high schools of study.

NOTES

1. Rogers is Janet M. Peck Professor of International Communication at Stanford University; in 1985 he will become Professor and Associate Dean of the Annenberg School of Communications at the University of Southern California. McManus and Peters are Ph.D. candidates in Communication, all in the Institute for Communication Research. Dr. Kim is Assistant Professor in the Department of Communication at the University of Hawaii-Manoa.

2. An algorithm is a stepwise procedure for solving a problem or accomplishing some end.

3. In support of the innovation process model, we note that the pattern discovered is partly a result of the location of the high schools studied, in and around Silicon Valley. This is an area of the country where the likelihood of receiving a computer as a gift, and the probability of parents being familiar with computers and convinced of their importance, is extremely high. Hewlett-Packard, for example, has a program of giving computers to schools enrolling the children of its employees. IBM, on the other hand, uses economic criteria, giving equipment to schools serving the disadvantaged. A national survey conducted by the Corporation for Public Broadcasting in 1983 indicated that U.S. schools averaged five computer work stations each. In comparison, our schools of study averaged 30. Receiving a gift of computers is hardly unique to Silicon Valley high schools, however. National surveys (Becker and others, 1983a, 1983b, 1984a, 1984b) indicate that half of the computers obtained by schools are donated.

4. The convergence model of communication can be defined in terms of its two cardinal words "convergence" and "communication." Kincaid and Rogers (1981) define communication as "a process in which participants create and share information with one another in order to reach a mutual understanding." Convergence is defined as "the tendency for two or more individuals to move toward one point, or for one individual to move toward another, and to unite in a common interest or focus."

5. Most of the microcomputers at one high school of study are tied up in teaching a "computer literacy" module required of each freshman. Since this program has just begun, upperclassmen are excluded from access. In another high school, computer classes are reserved primarily for mathematics students. Parents have complained about lack of access in both of these cases.

6. The results of the present study are consistent with a national survey by Johns Hopkins University's Center for Social Organization of Schools. Over time there has been a shift from the individual teacher sparking the innovation, to the involvement of principals and groups of teachers as the force shaping the diffusion of

microcomputers within schools (Becker and others, 1984a).

7. Apple finally settled for donating a microcomputer to each California school applying under a tax package approved by the California legislature in 1983.

8. Chen (1984) found gender differences in the computer programming courses but not in other courses in which computers were used: "Boys tended to enroll in high school programming courses in greater percentages...However, no difference was found in high school use of computers in non-programming classes (e.g., business and vocational classes using word-processing or other applications software). Girls were enrolled in these computer-using classes in roughly equal proportion to boys."

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Appendix A

CASE STUDIES OF THE DIFFUSION OF MICROCOMPUTERS IN NINE CALIFORNIA HIGH SCHOOLS

CASE STUDY 1: ARAGON HIGH SCHOOL (San Mateo)

PROFILE:
Number of students: 1,500
Proportion minority: 26%
Major minority groups and proportion: Asian 13%; Hispanic 9%
School community: "Suburban," middle and upper middle class.
Predominant program: College preparation; approximately 75% continue their education.
Number of microcomputers in 1984: 18
Number of microcomputers expected in 1985: 40

INITIATION STAGE ONE: AGENDA-SETTING

When the present principal, Robert Palazzi, came to Aragon High School in 1980, not only was there little interest in educational applications of microcomputers, but the previous principal had sold or given away all but one TRS-80 due to frustration over servicing problems. The school had experimented with computers, found them unsuitable and nearly terminated the innovation by the time that Palazzi arrived. In 1980, most teachers were either opposed or indifferent to microcomputers.

Within the high school, microcomputer applications in 1980 consisted of use in Special Education classes and what Palazzi called "a trickle" of interest in the school's business department. Outside the school, the agenda was far broader. There was considerable pressure both from many students and their parents to incorporate microcomputers across the high school's curriculum.

INITIATION STAGE TWO: MATCHING

Responding to a nascent interest in microcomputer

applications within the high school and to suggestions from parents and students, Palazzi formed a computer committee chaired by the director of social studies, Don Hill. The committee meets regularly to discuss and supervise school applications of computers. This relatively centralized approach to diffusion within the school led to matching microcomputer technology with specific classroom applications.

The applications that the committee decided upon were unique among the schools in our study. Microcomputers were to be introduced to all students as part of Aragon's "writing project." Each student would be required to become familiar with the word processing capacity of microcomputers. At least at first, the high school would not teach computer programming--the most common application at other high schools.

Requiring all students to experience the microcomputer "hands on" was a deliberate choice by Palazzi and the Aragon High School computer committee. The decision had two immediate purposes: (1) to refute the notion that microcomputers are only for mathematically-gifted students or for science classes; (2) to draw in teachers who were otherwise unlikely to use computers in their classrooms.

The decision not to teach computer programming was closely related to the school's policy on the writing project. Palazzi explained that the committee wanted to keep the influence of microcomputers spread across the curriculum, rather than isolated in a single department, such as mathematics.

At the matching stage in the innovation process, Palazzi,

the innovator, delegated authority to a committee of teachers, thus spreading responsibility for the successful implementation of microcomputers. Unlike many other high schools, there does not appear to have been a computer champion--a teacher or administrator personally knowledgeable about computers--who establishes the innovation, often through example. Palazzi does not characterize himself as a "convert" to computers. He maintains that there is "no room for another machine in my life now--I feel I can function quite well without one."

In addition to deciding how computers ought to be applied to the curriculum, Aragon's principal and faculty had to find money to buy the machines and their software programs. As with the other high schools of study, the regular school budget was too tightly stretched to include such purchases.

The key to implementation was a state Department of Eduation "Local Staff Development Grant." This grant provides $11,000 annually and is renewable for these future years. Only one quarter of the money may be spent for equipment; the rest must go for teacher training. The provisions of the state grant reversed the pattern in most schools of study where the microcomputer hardware is obtained before teachers are trained. At Aragon High School, Palazzi was able to grant teachers release time and send them to microcomputer training conferences and workshops before, or at the same time as the machines arrived in the high school.

With teacher training begun, Aragon diverted Chapter 2 funds earmarked for library acquisitions, to buy five Apple microcomputers in 1982. The parent-teacher organization at

Aragon raised money to buy six more Apples and another was received from Apple's California school gift program. Between the staff development grant and other money not spent where it had been committed, six TRS-80's also were purchased.

IMPLEMENTATION STAGE ONE: REDEFINING/RESTRUCTURING

Aragon High School's microcomputer diffusion has a built-in mechanism for redefining applications of the new technology to the curriculum--the yearly plan submitted to the State of California for the staff development grant.

The most important redefining and restructuring activities take place in (1) curriculum changes--the establishment of new courses made possible by the microcomputer; and (2) pedagogical changes --innovative ways of teaching traditional school subjects.

Several new courses using the microcomputer are planned for Fall, 1984, including "Computers in Mathematics," and "Computers in Business." With its expanding microcomputer capability, Aragon High School has been able to coordinate with the College of San Mateo--where many Aragon graduates continue their education--in accepting a $40,000 corporate grant to create advanced computer electronics classes. The elementary levels of such industrial arts classes will be taught at Aragon, with upper level courses at the College. The resulting graduates will fill a gap in the Bay Area labor market for electronic technicians.

Pedagogical changes, the second type of redefinition occuring with the implementation of microcomputers, accompany the expanded

curriculum. The most obvious examples are an electronic gradebook that eight teachers have adopted, and teaching English composition with the microcomputer in the computer awareness module required of all entering students.

In order to make these instructional changes, teachers are restructuring their own skills, both through training programs and conferences that Aragon has provided, and through the network of peer-to-peer interactions of decentralized diffusion. Jim Schaml, who is teaching the computer electronics course, and Jordan Nerl, chair of the science department at Aragon, provide an example of diffusion among colleagues.

Schaml bought an Apple II-plus after working during the summer with a computer pioneer in a nearby school district. Schaml felt he needed personal familiarity with a microcomputer because he was embarassed when his students asked questions about micros that he could not answer. Schaml's purchase of a microcomputer as a necessary--and tax deductible--tool for the modern teacher convinced Nerl that he too ought to buy a personal computer. After a summer computer workshop, Nerl purchased an Apple. The two teachers are frequently on the phone with each other and with other new users expanding their computer knowledge and breaking down fears of the new technology.

IMPLEMENTATION STAGE TWO: CLARIFYING

As with other schools that we studied, Aragon High School appears to have just begun the clarifying stage, where appropriate uses of microcomputers are becoming well-defined.

The stages in the innovation process are not mutually exclusive, of course, and at Aragon High School computer applications are still being created and restructured. The clarifying stage, however, has presently begun to be the focus of attention.

Perhaps the central issue undergoing clarification is the physical distribution of microcomputers in the high school. A debate growing out of the matching stage between faculty proponents of the Apple and those for the TRS-80 led to the establishment of two separate computer centers. One locus, in the business department, contains the seven TRS-80s. The room has its own personality, unadorned and "businesslike." The 11 Apples are located in a room with Nineteenth Century art prints on the wall to lend what social science director Don Hill calls "a humanistic flavor." While Palazzi settled the debate about the merits of the two brands of microcomputers with Solomonic wisdom by creating separate locations, the inefficiencies of such a division argue for a more logical clarification.

Another area of clarification is presently occuring for the funding for microcomputers. The computer committee's plan calls for 20 TRS-80s and 20 Apples by 1985, yet neither Palazzi nor Hill have identified the requisite funds. There is hope, however, that the school district will close on the sale of a parcel of property and make some of the proceeds available for microcomputer purchase. Although a one-time action, direct district subsidization of microcomputers would represent further definition of its support for computer innovation.

Farthest along in the clarification process is the computer

awareness strand of the Aragon Writing Project, required in 1983-84 for the first time of all freshman students. That segment, which consists of writing one assignment on a microcomputer word processing program, moves from the spring semester to the fall in 1984, so that freshmen will take it in their first term at school.

IMPLEMENTATION STAGE THREE: ROUTINIZATION

Perhaps within several years, the computer awareness module will be stable enough in content and placement in the curriculum for it then to be considered a routine application. At present, however, it is premature to consider any applications of microcomputers at Aragon routinized--the last step in our model of the innovation process.

CASE STUDY 2: CAPUCHINO HIGH SCHOOL (San Bruno)

PROFILE:
Number of students: 1,620
Proportion minority: 21%
Major minority groups: Hispanic 11%; Asian 8%
School community: Middle class parents in skilled blue-collar occupations.
Predominant program: Strong vocational orientation; 42% continue their education.
Number of microcomputers in 1984: 50 plus two terminals

INITIATION STAGE ONE: AGENDA-SETTING

The earliest agenda-setting for microcomputer applications at Capuchino High School involved the search in 1977 for a better way to teach mathematics and languages to slower students. The school was already using two terminals to access the San Mateo Union High School District HP-2000 computer in order to help students match their interests and abilities with career information. That program's success opened the door for computers to replace humans in certain other routine capacities. The microcomputers beginning to reach the market in the late 1970's promised relief for teachers in the repetitive drill-and-practice sessions typical of remediation. Principal Sam Johnson saw the tirelessness or the microcomputer as its main advantage over human teachers. As he put it: "Computers never get tired of kids, as teachers do."

INITIATION STAGE TWO: MATCHING

Johnson, and particularly Roger Selsback, head of the business department at Capuchino, were the computer champions at

the school. Both took an early personal interest in microcomputing. They suggested that the new machines might provide an ideal match for the problems of remedial classes.

Selsback began to see applications of the computer for teaching business long before Capuchino bought its first microcomputer. Following the lead of Dick O'Mallory, his predecessor as head of the business department, Selsback used the high school's terminals to teach his students accounting. In 1976, Selsback bought his first personal computer, an Apple I. Since then he has purchased two other home computers.

Selsback typifies a force for school innovation that has gained recognition in past diffusion research, the computer buff or computer champion (Sheingold and others, 1983). With Johnson's enthusiastic cooperation--the principal had also become a home computer owner--Selsback's interest in microcomputers spread among other faculty, students, and parents. Although the diffusion pattern typically identified with the computer champion is decentralized, at Capuchino Johnson's alliance with Selsback meant that the computer in the classroom would become a school-wide educational priority rather than an innovation adopted hit-or-miss by one or more interested teachers.

Besides having a microcomputer champion and the principal working hand-in-glove, the innovation had two other things going for it. First, Capuchino obtained a four-year state grant (1979-1983), totalling $400,000, to assist in the merger of Capuchino with its nearby sister--and rival--high school, Crestmoor. The money funded most of Capuchino's microcomputer

purchases. Second, Capuchino, as part of the State of California grant, underwent a self-study of each aspect of the school's mission. One of the important goals identified in the study was matching the microcomputer to the curriculum.

IMPLEMENTATION STAGE ONE: REDEFINING/RESTRUCTURING

Although the first applications of microcomputers at Capuchino High School were well-planned, classroom uses have been restructured so that they reach well beyond remedial drill-and-practice and career guidance.

Capuchino's first use of computers was through two DECWriter terminals connected to an HP-2000 minicomputer at the San Mateo Union High School District office. On these terminals students called up career information. Soon after, during the 1978 school year, Capuchino purchased two TRS-80's upon which students practiced mathematics and language skills.

With the merger of Capuchino and Crestmoor High Schools in 1980, two more TRS-80's were acquired from Crestmoor. During the 1980-81 school year, Capuchino's first School Improvement Program grant of $23,000 bought 16 TRS-80's which were placed in a computer center. Two years later the school boasted 30 TRS-80's, one Apple IIe, and the two DECWriter terminals.

In 1984, Capuchino began to disperse its growing system of microcomputers to reflect new course applications. By the beginning of the fall term, 1984, the school owned 50 microcomputers located as follows:

(1) Computer lab--29 TRS-80's and one Apple Macintosh.

(2) Special Education--four TRS-80's.

(3) Business Department--four TRS-80's.

(4) Career Center--two TRS-80's and two Apples.

(5) Industrial Arts--three Apple IIe's.

(6) Main office--two TRS-80's and one Macintosh.

(7) Testing Center--one TRS-80.

(8) Music Department--one Apple IIe.

Proceeding at the same pace as purchases of microcomputers has been staff training. With grant money to spend, Principal Johnson and computer champion Selsback were able to put on a series of in-service courses on microcomputers, as well as summer camp/workshops, lectures, and visits to other schools using microcomputers. While directed primarily at the faculty, some training was also offered to students and their parents.

IMPLEMENTATION STAGE TWO: CLARIFYING

Although seen first as a resource for "special" classes such as remedial education or computer programming, the microcomputer's uses have been clarified at Capuchino, so that now regular classes also take advantage of the new technology. A new skill useful for implementing the microcomputer in regular classes is learning to write software for one's own classes, rather than relying on commercial courseware. Acquisition of that skill marks a significant clarification of the microcomputer's meaning as a teaching resource.

The effort to bring microcomputers into the mainstream of education at Capuchino consisted of three main events:

Summer, 1981 -- Selsback explored software programs with faculty members through a summer planning grant. Computers were used to help students develop remedial English and mathematics skills. Selsback and colleague Jim Friedman developed a model peer tutoring program using the microcomputer.

1981-82 --Chuck Kent developed a microcomputer testing program that allows students to move at their own pace in the Safety Education Program.

1982-83 -- A microcomputer program was developed to provide teachers with information on reading level scores, competency test results, and learning classifications.

Fall, 1983 -- Kurt Krueger taught computer drafting to his industrial arts classes.

IMPLEMENTATION STAGE THREE: ROUTINIZATION

The steady spread of microcomputer applications throughout the curriculum at Capuchino, and the revision of older computer uses--such as writing remedial software "in house"--is evidence that the innovation has not yet become routinized. As is the case of the other nine schools of study, virtually no area of computerized instruction has remained static. New, more powerful machines, more appropriate software, and more creative utilization strategies give the microcomputer's educational applications an evolutionary character.

At Capuchino, the best bets for routinization are the oldest applications, drill-and-practice in remedial classes. Here use of the computer is well enough defined, perhaps, to be considered

standard practice. The main focus of attention at Capuchino and other schools that we studied, however, remains at the clarification and perhaps even the redefinition/restructuring stages of implementation.

CASE STUDY 3: LOS ALTOS HIGH SCHOOL (Los Altos)

PROFILE
Number of students: 1,900
Proportion minority: 25%
Major minority groups: Asian 9%; Hispanic 8%
School community: Upper middle class, children of Silicon Valley professionals.
Predominant Program: College preparation; 86% continue their education.
Number of microcomputers in 1984: 36

INITIATION STAGE ONE: AGENDA-SETTING

Los Altos High School is unique among the schools participating in the present study for its early recognition of the roles that computers can play in education and for the complete break between the school's use of mainframe computers and its later applications of microcomputers. There are really two separate computer innovations to describe at Los Altos, and their contrast showcases several principles of diffusion.

The first agenda-setting stage at Los Altos High School occurred during 1966 in the home of an innovative teacher, Virginia Kurzweil. Married to an electrical engineer and convinced that computers would profoundly affect the business world, Mrs. Kurzweil decided that her business students could gain an advantage if she taught them how to use the mainframe machines then coming into use at large American corporations. Like many other computer champions, Mrs. Kurzweil set the agenda personally, rather than in consultation with other teachers and the school's administrators.

The second agenda-setting stage at Los Altos High School did

not take place until 15 years later, in 1981 when the Mountain View-Los Altos School District closed the "old" Mountain View High School and redistributed students between Los Altos High and Awalt High School (which then became the "new" Mountain View High School). With the redistricting a new computer champion, John Woodworth, came to Los Altos High School to teach computer science. Shortly thereafter, Los Altos was designated by IBM to receive 15 microcomputers. The corporate gift came with strings that helped determine the agenda for the innovation. The computers were to be placed in a central area, rather than dispersed to classrooms. The school was to be responsible for maintenance, repairs, software, supplies, and peripheral needs. And IBM strongly recommended a program of teacher training.

In contrast to the first agenda-setting stage, the second involved more than one actor. Even had Woodworth desired autonomy, the conditions of the IBM gift forced the school to take responsibility for making microcomputers fit educational needs.

INITITATION STAGE TWO: MATCHING

At the first matching stage between computers and classroom applications at Los Altos High School, Mrs. Kurzweil, acting independently, taught her business classes the languages for the IBM 1401 mainframe computer. Mrs. Kurzweil used programming manuals that her husband fished out of a refuse barrel where he worked, to be used as the class texts. She taught herself from the manuals, reading one week what she would teach her students

the next. For four years between 1967 and 1971, her students studied the logic of the computer, but did not work directly with any machine. None was yet available to them.

The second matching stage (for microcomputers) was quite different. Rather than one teacher creating her own curriculum, 30 teachers took a month-long workshop at no personal cost to familiarize themselves with the IBM PC and how it might help them as instructors. That summer (1983), five teachers paid to take in-depth training on the IBM PC which lasted several months. And in this case, the high school, not one teacher, was responsible for instructional materials.

IMPLEMENTATION STAGE ONE: REDEFINING/RESTRUCTURING

In 1971, the Mountain View-Los Altos School District purchased a NCR Century 100 computer. Mrs. Kurzweil's students gained access to the machine, although they were assigned the lowest priority in using it. The district computer allowed Mrs. Kurzweil to redefine her classes from pure theory to theory and application. The computer was not conceived by district administrator, however, as a learning tool for students, so Mrs. Kurzweil's classes often waited six weeks for their programs to be run (from punched cards input). The teacher's solution was a Friday night session with interested students at the district office which her husband, Dr. Fred Kurzweil, would join. Some of the sessions held the students' interest until 2 or 3 a.m. Though generally applauded by parents, there was an occasional complaint about the propriety of students being out so late with

a teacher.

In 1972, Mrs. Kurzweil was instrumental in obtaining a $30,000 DEC PDP8-E minicomputer for Los Altos High School. The new machine and a $5,000 teletype she convinced the district to buy for it, permitted her to restructure her business courses once again, this time into a four-year sequence of computer study.

The redefining/restructuring phase for microcomputers began, in the fall of 1983 with the arrival of the 15 IBM PC's. Instead of these microcomputers transforming only business courses, teachers trained in using microcomputers brought their new knowledge to classes in English, industrial arts, mathematics, science, and vocational education.

IMPLEMENTATION STAGE TWO: CLARIFICATION

As Mrs. Kurzweil refined her use of the DEC minicomputer and developed her four-year curriculum in computer study, the products of her erforts, her students, began to demonstrate virtuosity. In 1972, 1973, and in 1976 her students won the California State Business Student of the Year Award. Mrs. Kurzweil's personal fame was also spreading.

What was apparently not spreading at Los Altos High School was enthusiasm among other teachers for using the DEC minicomputer in their classes. Nor did the students enrolled in Mrs. Kurzweil's business classes demand that more teachers be added to teach with the computer. Meanwhile there were signs the district was growing weary of paying $300 a month for routine

maintenance on the DEC computer.

In 1981, Mrs. Kurzweil retired from Los Altos High School and took a job with Stanford University. Her innovative teaching applications with the DEC and its applications withered in her absence, never making it to the routinization stage. In the same year, the school sold most of the equipment that Mrs. Kurzweil had accumulated, including the DEC minicomputer.

The implementation of microcomputers at Los Altos High School began in 1983. The clarification process is now just beginning, as teachers trade techniques and the school purchases new instructional programming. At this point, most classes are taught within the Department of Computer Science, headed by Woodworth. Five computer programming classes are taught, each with about 30 students working with 15 Apples. The IBM PC's, in an adjoining room, can be used by any class in the school for a variety of instructional applications.

One major clarification began in 1983, the establishment of a school-to-home computer network. With the purchase of a modem--a machine that connects a home terminal or computer through the telephone to another computer--the 70 percent of Los Altos parents who own home computers will soon be able to check their student's daily progress on a frequently updated "electronic gradebook." This important administrative use of computers by the school occured quite independently of the instructional uses.

IMPLEMENTATION STAGE THREE: ROUTINIZATION

It is too early to judge whether microcomputers at Los Altos High School will reach the routinization stage, where they are an accepted part of the curriculum and are no longer considered new. Efforts to adopt the mainframe computer to classroom applications during the 1970s clearly failed to make it to routinization.

There was a consistent difference, however, in the two innovation processes. At each stage in the process, Mrs. Kurzweil's adoption of the computer to the classroom was a one-woman show. Described by one of her colleagues as "not much of a team player," she did not stimulate their imitation. And except for the administration's purchase of the teletype to go with the donated DEC minicomputer, there appears to have been less than ideal administrative support for the innovation. In fact, a district official joked about the DEC "One more gift like that and we'll go under."

In contrast, microcomputers have enjoyed the support of the school administration at Los Altos and a number of teachers from the beginning. Such broad support appears to be necessary for an innovation to flourish once the innovation champion has left a system.

CASE STUDY 4: MILPITAS HIGH SCHOOL (Milpitas)

PROFILE:
Number of students: 2,100
Proportion Minority: 42%
Major minority groups: Hispanic 15%; Black 10%; Filipino 9%;Asian 8%
School community: Blue-collar turning to high-tech professionals.
Predominant program: Mixed, vocational and college preparatory.
Number of microcomputers in 1984: 30 (and 2 minicomputers).

INITIATION STAGE ONE: AGENDA-SETTING

Assistant Principal Paul Wrubel's sensitivity to the changing demographics of the community surrounding Milpitas High School in 1979 was the spark that began his consideration of adding the microcomputer to the school's set of educational tools. With Silicon Valley's microcomputer industry expanding into Milpitas, more students were coming to the school each year seeking preparation for a four-year college. The adoption of microcomputers became one part of a plan to update and enhance the high school's curriculum. It just seemed "intutively right," said Wrubel, "to join the Computer Age."

Wrubel also had an administrative reason for introducing microcomputers into Milpitas High: The machines allowed less-skilled employees to complete more administrative work than more skilled people had previously accomplished.

INITIATION STAGE TWO: MATCHING

By 1979, Wrubel had decided that the computer was an important educational asset, but he was unsure how it might offer

solutions to match Milpitas High School's academic needs. He decided to get help. In 1980 Wrubel recommended the hiring of Bob Macartney, a math and physics teacher who had been laid off from the Fremont Union High School District, to become his school's computer champion.

Later that year, Wrubel and Macartney traveled to nearby Saratoga High School to see how that school used its 15 Apple IIs. The visitors discovered that Saratoga students kept the machines busy from when the school opened its doors in the morning, to 6 p.m. Afterwards, Wrubel said he sensed the microcomputers provided what for him is the key educational need -- a sense of excitement about learning. "I don't give a damn whether you're learning to tie your shoes," he said. "The important thing is to get turned on to the process of learning."

IMPLEMENTATION STAGE ONE: REDEFINING/RESTRUCTURING

The Milpitas High School computer system began with seven terminals connected via dedicated telephone lines to the school district's central computer. The first computer classes were taught in January, 1982, relatively late compared to neighboring schools. Since then the school has added 30 microcomputers. And in the spring of 1983, Milpitas received two donated DEC PDP-1145 minicomputers, which school officials estimate are worth $200,000.

Milpitas has gone against the centralization trend evident in other schools of putting al the microcomputers in a computer lab or center. Milpitas does have 14 micros in a computer room,

but the rest are in scattered locations: Two in the business department, two in the science department, three in Special Education, one in industrial arts, and eight in remedial classrooms.

As Rogers' (1983) model of the innovation process points out, there are two dimensions to the redefining/restructuring stage. Not only is the innovation changed to accommodate to the specific needs of the adopting organization, but the organization is altered as well. The first applications of computers at Milpitas High School were administrative, but soon they were redefined for academic purposes, specifically to teach computer programming. About 15 Milpitas' teachers redefined their classroom protocols to include the computer. Of these, five teachers teach mathematics using the new machines; two teach business; two, special education; two, science; and four adopting teachers are in other disciplines.

IMPLEMENTATION STAGE TWO: CLARIFICATION

Microcomputer adoption by the end of the 1983-84 school year had reached 19 percent of the faculty of 80 teachers -- a remarkable rate of diffusion in a relatively short time. Among these faculty, the clarification process has begun. Microcomputer uses are being refined and generally expanded. As with most other schools in our study, however, the redefinition/restructuring stage continues. More of the faculty and a greater proportion of the student body began using microcomputers in 1984-85 when a word processing capability was

added.

Our personal interviews with teachers and administrators at Milpitas High School suggest five factors have made the diffusion process move so quickly at Milpitas. First, championship of the innovation originated with the assistant principal. Second, one teacher, Macartney, was encouraged to become an "in-house" expert. Three, computer training programs included a number of teachers from the beginning. Four, funding was available for purchasing microcomputers through School Improvement Program grants, district support, and from corporate donations. Five, the decentralized positioning of the microcomputer hardware made it accessible to teachers in disciplines other than just business and mathematics, the most common subjects in which microcomputers are used at other high schools.

IMPLEMENTATION STAGE THREE: ROUTINIZATION

For Milpitas, more than most of the high schools in the Stanford study, it is premature to talk of "routine" uses of microcomputers. Only computer programming classes, which now enroll close to 300 of Milpitas' 2,100 students, might be considered a stable application of microcomputers. But even here, changes are reported and an expansion into more sophisticated programming languages such as PASCAL is underway. Classes in computer programming have only been offered since 1982. So Milpitas High School represents a system in which computers have gotten off to a promising start.

CASE STUDY 5: MOUNTAIN VIEW HIGH SCHOOL (Mountain View)

PROFILE:
Number of students: 1,550
Proportion minority: 25%
Major minority groups: Hispanic, 10%; Asian, 9%
School community: Middle and upper-middle class.
Predominant program: College-prep; 83% continue their education
Number of microcomputers in 1984: 24
Number of microcomputers expected by 1985: 34

INITIATION STAGE ONE: AGENDA-SETTING

The agenda-setting stage for microcomputers at Mountain View High School was a logical extension of the innovation process for mainframe computers. The Mountain View-Los Altos School District introduced daily demand modular scheduling in 1970. The program proved so cumbersome to operate that in 1971 the District obtained an IBM 1620 to administer the scheduling program. Having turned to the computer to solve administrative problems, it seemed logical to District administrators to use it for academic applications. In fact, one teacher at Los Altos High School had already begun to use the IBM for her business classes (see our Case Study #3). In the mid-1970s, the District decided to allocate $15,000 for the purchase of computers. That appropriation, however, went to other schools than Mountain View. By the time Mountain View (then named Awalt) High School's turn came, Proposition 13 had stripped school budgets of all but minimum operating funds.

Despite this lack of funding support from the district, microcomputers remained on the agenda at Mountain View High School. Students demanded them. In 1976, mathematics teacher

William "Sandy" Wagner was "drafted," he said, by students to teach computing. And in 1981, a Special Education student, acting without the knowledge of the principal, persuaded a nearby computer company to donate $16,000 worth of equipment to Mountain View High.

INITIATION STAGE TWO: MATCHING

The District was interested in the application of computers to teaching. The students were interested. The parents were interested. And now a teacher had been enlisted to champion the innovation. The process of matching the microcomputer's capabilities to the educational needs of Mountain View High School students could begin. The California School Improvement Program (SIP) was to be the vehicle driving this effort, as it has been in several other schools in our study (see particularly our Case Study #2). SIP funds, which provide about $65 per student annually, were used to buy 23 Apples over four years and to fund teacher training on the use of microcomputers.

The original matches of computer and classroom were typically conservative. The new machines were first used to teach computer programming.

IMPLEMENTATION STAGE ONE: REDEFINING/RESTRUCTURING

As is the case with all nine high schools in our study, the principal task at the redefinition stage involves training teachers to change their pedagogical methods to take advantage of the capabilities of the microcomputer. At Mountain View, the SIP

funds allowed Principal Thomas Lorch to pay for that training and to permit release time for teachers to learn about computers.

Some cases of classroom restructuring at Mountain View High are:

1. Marilyn Baldauf, an English teacher, uses microcomputers as motivating and time-saving instruments, both with her most advanced classes and her remedial students. One-third of her students below grade level are newly-arrived youngsters from Southeast Asia.

Students with little academic interest are stimulated by using the word processing capability of the computer, she said. They become "very excited" when their stories are printed out. With the computer, she noted, students are "anxious to make corrections," an unusual inclination among adolescents.

Baldauf describes the new machines as a "godsend" for students for whom English is a second language. She teaches with software that corrects spelling and grammar mistakes as well as drilling students in particular problems such as noun-verb agreement and capitalization. In addition, she uses a speed-reading package that can be adjusted from rates of 50 to 1,000 words per minute. Lastly, the videogame capacity of the microcomputer allows her to reward students with educational games such as "Crossword Magic," and "Hangman."

2. Gary Bonnano teaches small classes that focus on "basic skill development" for students who are falling behind their peers. These students -- many of whom have short attention spans and little tolerance or frustration -- enjoy working on

microcomputers because they give immediate results and instant reinforcement. They also reduce the "negative ego-stress' of being corrected by another human.

3. John Reisdorf teaches classes in woodworking. He is assisted by an Apple microcomputer, a disk drive, and an Epson printer for hardware, and software from the Iowa Handbook of BASIC Computer Programs. The microcomputer performs such tasks as calculating the total amount of wood needed for a student project and its cost.

IMPLEMENTATION STAGE TWO: CLARIFICATION

Clarification typically occurs at two levels within a high school. At the classroom level, teachers change their approach to students to take advantage of the microcomputer; and at the school level, decisions are made and refined about where to physically locate the scarce resource of microcomputers.

As with all schools studied in our Stanford project, the redefinition/restructuring stage coexists with the clarification stage at Mountain View High School. Redefinition continues -- especially for teachers who are just undergoing computer training or adoption -- while those who have decided to use the computer upgrade their skills or perhaps write more appropriate instructional programs.

The faculty at Mountain View expect to receive 10 donated Hewlett-Packard microcomputers in late 1984. These additions will bring the school's total to 34 micros, have fueled a clarification debate over whether a central location is superior

to the present decentralized placement of the machines (12 in the computer lab, one in the tutorial center, one in special education, one in the career center, three in the remedial reading/writing classroom, one in industrial arts, two in science, one in the library, and one used for writing the student newspaper). Critics or the present location policy speak of unequal access and a lack of coordination between "pockets" of microcomputers. Proponents of decentralization argue for the convenience and familiarity of a computer sitting in the classroom. This decision about computer location is copntroversial and was still in process at the time of our data gathering.

IMPLEMENTATION STAGE THREE: ROUTINIZATION

Although Mountain View High bought its first microcomputer in 1975 (a pre-assembled M-SCI), the bulk of its complement did not arrive until after 1978, when School Improvement Program funding began. The changing nature of hardware and software, plus the continuing debate over the location and applications of microcomputers, indicates that microcomputers are not yet routinized at Mountain View High School. The same conclusion holds for every other high school in our study, for the same reasons.

CASE STUDY 6: SAN JOSE HIGH SCHOOL (San Jose)

PROFILE:
Number of students: 1,100
Proportion minority: 84%
Major minority groups and proportion: Hispanic 59%; Asian 20%
School community: Blue-collar with very high family turnover.
Number of microcomputers in 1984: 24

INITIATION STAGE ONE: AGENDA-SETTING

There is little recollection among the faculty members interviewed at San Jose High School of planning for microcomputer applications for either academic or administrative tasks. A lack of continuity in the school's administration--four principals in as many years--is partly the reason. But San Jose High School, perhaps more than any other school of study, appears to have been overwhelmed with donated computers before classroom uses could be found for them. Unlike our other high schools of study, there appears to have been no computer champion at San Jose High School to provide expertise to other teachers and to "spearhead" the innovation. The lack of an internal motivator able to demonstrate classroom microcomputer applications and to lobby for their diffusion to other teachers may explain the rather casual approach that San Jose High School has taken to this innovation. In sum, the agenda-setting stage was somewhat rudimentary.

INITIATION STAGE TWO: MATCHING

As with agenda-setting, there appears to have been little effort expended in deciding with which specific classes and administrative tasks microcomputers might assist. There was one

exception. Dr. Sam Rodriguez, the principal from 1982 to the summer of 1984, envisioned the school's clerical staff using microcomputers for word processing and record-keeping.

IMPLEMENTATION STAGE ONE: REDEFINING/RESTRUCTURING

The implementation process at San Jose High School, as at two other high schools of study, underwent a false start. Five computer terminals and two Apple microcomputers, obtained in the spring of 1982 were stolen in June of that year, before patterns of infrastructural use had time to develop.

Since then, San Jose High School has received a number of donated computers, but due to various reasons, has yet to put them all to use. San Jose High is unique among the nine schools of study in having a video arcade lounge. Pizza Time Theatres (which has since declared bankruptcy) donated the arcade games. The school uses the lounge to raise money that its students might otherwise spend off campus. The funds thus obtained are channeled to a scholarship fund.

There are four groups of instructional computers at San Jose High, so it is similar to about half our schools of study in choosing decentralized locations for their machines.

(1) Four Apples, donated by the Charles Stewart Mott Foundation, are placed in the Career Center. One is used for administrative word processing; the other three are used by students to help explore future occupations and to write resumes from a software package designed for that purpose.

(2) Five TRS-80s were purchased by the school in 1983. One

of these was assigned to the principal's secretary, following Dr. Rodriguez's wish that clerical tasks be performed on a computer. However, the secretary has made little use of the machine and has asked that it be placed elsewhere. The other four TRS-80s are used in two classes--reading and English composition--for "instructional management," i.e., recording students' grades and correcting multiple choice tests administered on the microcomputer screen.

(3) Also in 1983, Hewlett-Packard donated 10 HP-86s, several printers, software and manuals. The microcomputers are bolted to cafeteria tables in a makeshift computer laboratory. The machines are used primarily for computer programming classes. During the summer of 1984, six teachers recruited from different disciplines took the microcomputers home to learn how to use them.

(4) Lastly, Atari donated four 800s in 1983, which have yet to be assigned to an application. Assistant Principal Edward Freed conceded that he is "dragging his feet" on putting the Atari's to use, but said there is little compatible educational software for the machines (the Atari 800s mainly have videogame software).

Here we see how gifted microcomputers can lead to problems of compatibility.

IMPLEMENTATION STAGE TWO: CLARIFYING

Because San Jose High School is still finding uses for microcomputers already donated, the clarifying stage has yet to

be reached. The school has had only one year's experience with microcomputers. More time is needed before administrators and educators can assign a meaning to the new technology in San Jose High School's curriculum.

Obviously, the routinizing stage, when microcomputer uses are no longer perceived as an innovation, will not be reached for many years.

CASE STUDY 7: GEORGE WASHINGTON HIGH SCHOOL (San Francisco)

PROFILE:
Number of students: 2,918
Proportion minority: 79%
Major minority groups and proportions: Asian 50%; Black 15%; Hispanic 2%
School community: Middle class, ethnically diverse.
Predominant Program: College-preparatory; 78% continue their education.
Number of microcomputers 1984: 21
Number of microcomputers expected by 1985: 36

INITIATION STAGE ONE: AGENDA-SETTING

With its high minority enrollment, and unfortunate socioeconomic status--not poor enough to qualify for Federal or certain corporate grants, but not rich enough to pay its own way--George Washington High School is an unlikely setting for a nearly model process of microcomputer innovation.

Washington is a good example of the innovative climate that can be achieved when several important catalysts of diffusion are present in a system at the same time. The high school has a history of openness toward educational innovation--although many faculty members were originally skeptical, thinking that microcomputers might be just another fad. In addition, Washington had not one, but two, computer champions. Third, the school created a committee of faculty and administrators (called a "Quality Circle") who meet weekly to plan, raise funds for, and guide microcomputer applications.

George Washington High School's first academic experience with computers came in 1969, when the mathematics department

decided to teach FORTRAN programming with IBM cards, using the mainframe computer at the San Francisco School District Office. William Ferrero, a math teacher, and Helen McKenna, a science teacher, pioneered this computer innovation. Both saw the advantage of microcomputers for teaching at Washington, so by the mid-1970's the stage was set for implementation.

The high school's first administrative application of computers occurred in the late 1970's. To keep attendance and grade records, the school used an IBM at the San Francisco School District office. The Washington High School library also had two terminals for student use connected to an H-P 2000 minicomputer located at Woodrow Wilson High School.

Washington High received a further shove toward microcomputer adoption in 1980, when the San Francisco Unified School District discontinued renting a card punch machine needed to program the FORTRAN classwork. Every teacher in the mathematics and science departments by then realized that the school had to obtain microcomputers, which they characterized as educationally important and viewed as somewhat glamorous.

Microcomputers were expected to enable Washington (1) offer more computer programming classes so as to meet the increasing demand; (2) to improve the curriculum in subjects other than programming; and (3) to manage both classroom and school record-keeping more efficiently. At this stage, the school considered two alternative locations for microcomputers: Putting them all in one central location or dispersing them to various departments.

The availability of microcomputers and their implementation at other high schools were both important factors in the decision to adopt at Washington. In the summer of 1981, several Washington staff members visited Santa Rosa High School, Saratoga High School, and St. Ignatius High School. They also visited microcomputer companies in Silicon Valley.

INITIATION STAGE TWO: MATCHING

Between them, computer champions Ferrero and McKenna had spread their interest in microcomputer applications to several other teachers including the librarian; math chair; business department head and the gifted program coordinator, and to the new principal, Al Vidal. The school submitted a grant request to the district in 1981 for money to obtain microcomputers, but it was denied. Vidal decided to go to the community for support. He suggested a "Walk-for-Computers," that netted $7,000 in local donations. At the same time Washington formed a committee to make decisions about microcomputers, a so-called "Quality Circle" that was modeled after Japanese management style.

IMPLEMENTATION STAGE ONE: REDEFINING/RESTRUCTURING

Washington's first microcomputer purchase occurred in 1980 with the acquisition of one TRS-80 Model I's. The machines, as planned, were used to teach computer programming. The immediate popularity of the microcomputers encouraged the teaching staff to believe that students would readily accept the innovation, thus the scope of microcomputer applications, they decided, should

gradually be restructured to include more subjects. A father donated a second microcomputer to the school in 1981.

In September, 1982, District Superintendent Dr. Robert Alioto allocated $80,000 from district capital funds to assist Washington High School in purchasing more microcomputers. Students and faculty held a second "Walk-for-Computers." As a result, Washington was able to purchase 18 Apple IIe's, a CORVUS computer for networking the microcomputers in the computer lab, and a variety of software. Under the "Kid's Can't Wait" California Apple bill, the school received another Apple IIe in 1983.

IMPLEMENTATION STAGE TWO: CLARIFYING

In May, 1983, the Edward Gorham Computer Center was inaugurated, with the Quality Circle serving as its advisory board. The principal subjects taught with microcomputers were computer programming and word processing at this time. In order to expand applications of microcomputers throughout the high school curriculum, more teachers would have to be trained and more software purchased. So in the spring of 1983, the Quality Circle sought and obtained $15,000 for staff development from the state of California (under Bill AB551). The grant enabled Washington High School to buy additional software for staff/curriculum development, and to provide six hours of computer training to 90 teachers. The training was conducted by the school's computer teachers at the computer lab.

The enthusiasm of Washington's students for microcomputer

instruction led to another clarification of the new technology's role at the school. The Quality Circle decided to open the Computer Center at lunchtime to students on an individual basis.

IMPLEMENTATION STAGE THREE: ROUTINIZATION

Although Washington is closer to routinization than most of the other eight schools of study, the microcomputer is still a distinctly recognizable innovation. Most of the school's teachers are now familiar with the new machines, but have little in-depth knowledge. Applications of microcomputers to classes at Washington High School are still expanding, and existing uses are being modified as teachers and students become more comfortable with the innovation and as new courseware is obtained.

CASE STUDY 8: WILLOW GLEN HIGH SCHOOL (San Jose)

PROFILE
Number of students: 1,420
Proportion Minority: 25%
Major minority groups: Hispanic 19%; Asian 4%
School community: Middle to upper-middle class.
Predominant program: College preparation; 80% continue their education.
Number of microcomputers in 1984: 28
Number of microcomputers expected by 1985: 31

INITIATION STAGE ONE: AGENDA-SETTING

When Dan Jackson became principal of Willow Glen High School in November, 1980, the school had three microcomputers, two of which were prizes won by students in science contests. Two faculty members used computers, one in teaching science; the other had set up a student computer club. Outside of those two staff members, one of whom left Willow Glen shortly after Jackson arrived, the microcomputer was an alien machine using a technology many teachers thought took too much mathematical aptitude to master. Soon after he arrived, Jackson became the microcomputer champion at Willow Glen.

Jackson brought with him from Leland High School, where he had been principal for seven years, the knowledge that microcomputers could be obtained without using budgeted school funds. Leland parents and teacher David Dickenson had raised money to purchase 18 TRS-80's. Jackson also brought a conviction that all students would encounter the computer at work sometime in the near future, so the new technology ought to be introduced at school. This insight struck him when his two grown daughters

both began using microcomputers at their jobs.

INITIATION STAGE TWO: MATCHING

Because his reading of the future indicated that microcomputers would become involved in almost every field of work, Jackson hoped to give all students at Willow Glen at least a familiarity with microcomputers. "My dream is to have a room full of computers," he said. "I want every kid to learn a computer language. We can't be a comprehensive high school until kids get programming."

Another problem Jackson hoped that microcomputers might solve was motivating poor learners. "In high school," Jackson said, "we continue to teach them those skills in the same way they haven't learned them before. My whole idea was that the computer--in the hands of the right person--could maybe be more creative, teaching them in a different way."

Jackson also wanted to match the microcomputer to record-keeping, so that he could increase his surveillance over the progress of students and teachers. "I'd love to know," he said, "how many students get a B in a certain class, or an F." At present, such questions can only be answered after a laborious search of teachers' gradebooks.

As he had at Leland, Jackson's first step at Willow Glen was to organize the parent-teacher organization into an effective fund-raising unit. He persuaded the parents of the importance of microcomputers in a modern education, and worked out a five-year plan for their implementation. The parents responded with an

annual rummage sale and other events, and by 1984 had accumulated $5,000. The principal took the money to a computer sale and came back with 16 Commodore 64's, four disc drives, and two printers. The new machines were placed in what had been a stenography classroom. The room was renamed the Dan Jackson Computer Center to honor the principal, who retired at the end of the 1983-84 school year.

IMPLEMENTATION STAGE ONE: RESTRUCTURING/REDEFINING

In 1984, his retirement year, Jackson realized his dream of a "room-full of computers," but not the broad application to all students that he had envisioned, nor the specialized courses for remedial students. There was still not enough teacher training, nor an adequate number of microcomputers for such ambitious goals. But a start had been made. Tom Pannunzio, a business teacher, agreed to take computer courses in his spare time and assume leadership of the new computer center.

During the 1984-85 school year, eight to ten teachers (of a 70-member faculty) are expected to use microcomputers in some aspect of their instruction. The adoption by these teachers indicates the beginning of the process of redefining classroom practice in light of the new technology. Among the courses to use microcomputers are computer programming, science, nutrition education, career counseling, drafting, keyboarding (word processing), and bookkeeping. Administrative records are also being transferred to microcomputers. And the computing club has been revived, after a lapse of student and teacher interest.

IMPLEMENTATION STAGE TWO: CLARIFYING

Because microcomputers are so new to Willow Glen, the clarifying stage remains in the future. The high school is still in the midst of restructuring its classes to implement microcomputers. What they will mean to instruction at Willow Glen will probably not be clear for at least several more years.

CASE STUDY 9: WOODROW WILSON HIGH SCHOOL (San Francisco)

PROFILE
Number of students: 1,630
Proportion minority: 97%
Major minority groups: Black 38%; Asian 23%; Hispanic 19%; Filipino 17%
School community: Inner-city poverty with many recent immigrants.
Number of microcomputers in 1984: 13 plus 50 terminals (connected on site to two minicomputers).
Number of microcomputers expected by 1985: 23

INITIATION STAGE ONE: AGENDA-SETTING

As far back as 1970, Woodrow Wilson High School had seen applications of computers as a desireable way to educate unmotivated students, many of whom come from low-income neighborhoods near the school. In 1970, Wilson received an HP-2000 minicomputer as a gift. Since then, the school has added another HP-2000 and now has 50 terminals located in two computer laboratories. These laboratories are utilized from an hour before classes begin in the morning, through lunch time, until school closes in the afternoon. The extensive use of computer equipment has led the school to plan expansions of its system with microcomputers, which are less expensive and more easily updated than the larger minicomputers.

INITIATION STAGE TWO: MATCHING

At Wilson High School, Principal Hoover Liddell is the computer champion. Through a continuing grant from the San Francisco Unified School District, Liddell is able to pay 40 percent of the salary of Jim Green, a special assistant who is

knowledgeable about both mini- and microcomputers. With Green available to train faculty in computer applications, Wilson has more capability of expanding the match between microcomputers and pedagogical problems than most of our other eight schools of study. Other high schools typically must send teachers off-campus to learn about integrating the new technology into their instruction program.

Woodrow Wilson High School also has skillfully used its poverty status to acquire Federal, state, and private grant money to purchase computer equipment. So far, the school has spent very little of its regular budget on computers.

IMPLEMENTATION STAGE ONE: REDEFINING/RESTRUCTURING

Much of the academic style of Woodrow Wilson High School prior to 1970 has changed as a result of obtaining the minicomputer and terminals. Instructional computer applications at Wilson include:

(1) All remedial classes.

(2) All reading laboratory classes.

(3) All ESL (English as a Second Language) courses.

(4) Computer programming (10 classes in BASIC; one in PASCAL).

(5) Physical education.

(6) Business skills.

(7) One mathematics teacher uses the computer to analyze the distribution of student test scores.

(8) Word processing.

(9) EUREKA, a computerized career program used by 11th and 12th graders.

The school also uses computers for administrative tasks, and to send every student a birthday card on the proper day.

Currently, Wilson is experimenting with a Dynatel computerized telephone system. Dynatel automatically telephones parents each evening when their child has missed school, asking why the child was absent. If Dynatel reduces absenteeism, besides improving school performance, it would generate additional state revenue for Wilson because funding is based on attendance.

Most of the restructuring that has taken place at Wilson is due to the widespread introduction of computer terminals over the past 14 years. The school did not receive its first microcomputer until 1982, and had only 13 through 1983, so little academic redefinition can be claimed yet for microcomputers.

IMPLEMENTATION STAGE TWO: CLARIFYING

With 14 years of experience with computers, as much or more than any other of our schools of study, Wilson has found that the "patience" and instant response of educational computers has improved student motivation.

Over the next several years, as microcomputers take over some tasks previously assigned to minicomputers, their role in the school will be more clearly distinguishable from the part already played by the minicomputer and terminals.

Part of the clarifying experience at Wilson will undoubtedly be the founding of a Department of Technology. Principal Hoover

has long dreamed of establishing such a center.

IMPLEMENTATION STAGE THREE: ROUTINIZATION

Woodrow Wilson High School, of all our nine high schools of study, makes the best case that routinization is currently a difficult, if not impossible, stage for a school to reach. No other school has used computers so extensively for so long as Wilson. Yet just as use of terminals and minicomputers was becoming familiar, the microcomputer is changing the patterns of classroom application.

Appendix B

SUMMARY OF SITE VISITS TO THE NINE HIGH SCHOOLS OF STUDY

TABLE 2. SUMMARY OF SITE-VISITS TO NINE HIGH SCHOOLS WITH MICROCOMPUTERS.

High School/ Demographics	Computer Equipment/Location/ Time of Acquisition	Funding Sources	Major Applications	Innovator(s)/ Process
1. ARAGON H.S. (San Mateo) 1,500 students Middle-class, "suburban" school with 26% minorities and 22 languages; 13% Asian, 9% Hispanic Predominately college prep; 75% continue their education	Centralized 1980: All but one TRS-80 sold or given away in frustration over servicing costs. 1983: Two computer centers established with 7 TRS-80s in one, 11 Apples in the other. 1985: Expect 20 TRS-80s and 20 Apples. 1984 total: 18 micros 1985 expected total: 40	State staff development grant in 1982. Chapter II funds in 1982. Parent-teacher organization fund-raising. Kids Can't Wait program. No regular budget funding; fund procured "by hook or by crook".	Computer awareness unit in social studies required for all students. Grade-keeping. No computer programming. No remedial applications. By 1985, expect 3 classes in math, 6 in business, 1 in industrial arts.	Principal formed implementation committee. Centralized approach. Training grant will acquaint faculty with methods of teaching with computers. Pressure from parents and students to adopt micros. No computer champion, nor outside experts. Growing teacher interest, often hostile/apathetic beginnings.

TABLE 2. Summary (cont.)

High School/ Demographics	Computer Equipment/Location Time of Acquisition	Funding Sources	Major Applications	Innovator(s)/ Process
2. CAPUCHINO H.S. (San Bruno) 1,621 students 75 teachers; average class size of 28.5. Middle-class community of parents in skilled occupations; heavy vocational emphasis;42% continue their education. 21% minority; 11% Hispanic, 8% Asian.	Decentralized 2 DECwriter terminals to District minicomputers. 1978-79: 2 TRS-80's(from merger with Crestmoor H.S.) 1981-82: 17 TRS-80's. 1982-83: Each computer upgraded to 48K RAM; 9 TRS-80's. By 1984, Computer Lab had 29 TRS-80's, 1 Macintosh; Music Dept., Apple IIe; Industrial Arts, 3 Apple IIe's; Career Center, 2 TRS-80's, Apple II and Apple IIe; Main Office, 2 TRS-80's, 1 Macintosh; Business Dept, 4 TRS-80's; Testing Center 1 TRS-80; Special Education, 4 TRS-80's. Total Micros: 50	State School Improvement Program (SIP) Federal Vocational Education funds. No funding from regular school budget.	Computer Math (3 classes; business, word-processing, DECA club for computer enthusiasts. Much emphasis on computer-assisted instruction in other subject areas. Remedial English and Math; ESL; SAT preparation. Computer drafting in Industrial Arts Eureka (career guidance) Summer Computer Camp and workshops for students, staff and parents.	Principal and Business teacher. Diffusion through teacher-led training sessions.

TABLE 2. Summary (cont.)

High School/ Demographics	Computer Equipment/location Time of Acquisition	Funding Sources	Major Applications	Innovator(s)/ Process
3. LOS ALTOS H.S. (Los Altos) 1,890 students Mostly children of Silicon Valley professionals. Minorities total 25%: 9% Asian, 8% Hispanic. College-prep program with 86% of students continuing their education.	Centralized Business education: 1968 IBM keypunch; 1970 additional keypunch, teletypes(2), and modem. 1970:IBM 1620 for one year. 1972: DEC POP8-E computer, Pet micro. 1981: Most equipment above sold. 1984: 16 Apples, 15 IBM PC's, 3 Atari's, 1 Onyx, 1 Pet. Total Micros: 36	Corporate donations.	Learning data-processing programming Class Scheduling 4-year Computer curriculum, 1972-1981. Business classes. Computer science dept.	Early champion a teacher. No teacher-to-teacher diffusion in early period, but a pattern after 1981. Later champion came to school in merger with another school, but recently left.
4. MILPITAS H.S. (Milpitas) 2,100 students Mixed student body: Children of blue-collar workers joined increasingly by those of high-tech professionals. 42% minority: 15% Hispanic, 10% black 9% Filipino, 8% Asian	Decentralized Computer Room: 4 Apple IIs, 10 HP 86's, 7 terminals to Dist. computer, 2 DEC PDP 1145 minicomputers. Business dept: 2 Apple IIe's Science dept: 2 Apple IIe's Special Education: 3 Apple IIe's Industrial Arts: 1 Apple II. Tutorial Center: 8 Apple IIe's for remedial classes. 1984 Total: 32 micros or minis.	School Improvement Program. Corporate Donations No regular school funds.	Computer programming. Remedial classes. Industrial Arts. Class scheduling and record-keeping. 1984 expect word-processing.	Began as administrative rather than as educational tool. Micro champion brought in by principal to begin implementation (1980). Centralized coordination of diffusion. 15/80 teachers use micros in some courses.

TABLE 2. Summary (cont)

High School/ Demographics	Computer Equipment/Location Time of Acquisition	Funding Sources	Major Applications	Innovator(s)/ Process
5. MOUNTAIN VIEW HS (Mountain View) 1,560 students 25% minority: 10% Hispanic, 9% Asian. Predominantly college prep with 83% continuing their education.	Decentralized 1975: M-SCI 1978-83: 23 Apples: 12 in Computer Lab, 1 in Tutorial Center, 1 in Special Education, 1 in Career Center, 1 in Industrail arts, 2 in Science, 1 for student newspaper. 1 Altos in library. 1984 Total: 24 micros by 1985, expect 34 micros.	School Improvement Program. Donation arranged by a student. Corporate donations. No regular school funds.	Library Circulation records. Programming, drill and practice, word-processing, spelling program, speed reading, SAT preparation, formatting student newspaper. 1984 expect school-to-home micro network for electronic student files -- "electronic gradebook".	Math teacher responding to student pressure. Teacher-to-teacher diffusion. Decentralized.
6. SAN JOSE H.S. (San Jose) 1,100 students 84% minority: 20% Asian, 59% Hispanic Very high turnover of students Blue-collar parents.	1982: 2 Apples and 5 terminals stolen. 1982: 6 videogames. 1983: Career Center, 4 Apple IIe. Classrooms: 4 TRS-80's. Computer Lab: 5 Atari 800's, 10 HP-86's. Decentralized 1984 Totals: 24 micros	Mott Foundation Corporate donations. School funds.	Videogames, word-processing, career guidance, resume preparation, programming. Administration/ test correction Atari's idle, awaiting software.	Prinipal. Selected teachers permitted to take computer home for summer to learn how to use them. No "computer champion", nor outside expert hired.

TABLE 2. Summary (cont)

High School/ Demographics	Computer Equipment/Location Time of Acquisition	Funding Sources	Major Applications	Innovator(s)/ Process
7. WASHINGTON H.S. (San Francisco) 2,918 students 32 students per class. 79% minority: 50% Asian, 15% black, 2% Hispanic. Middle-class community.	Centralized 1970: used IBM mainframe at college. 1979-80: 3 TRS-80's 1981: librarian connects terminals to dist. minicomputer. 1982: 1 Apple. 1983: 16 Apple IIe's, CORVUS computer for networking. 1984 Total: 21 micros By 1985, expect 36.	"Walk for Computers" District capital funds State aid for staff training (AV551 Bill). "Gourmet Holiday Dinner" fundraiser. No regular school funds.	Programming, word-processing, data-processing. Staff training.	Physics and Math teachers early champions. "Quality Circle" of teachers makes implementation decisions. 1983, 90/127 teachers receive 6-hr. intro to micros; only 5-6 more skilled with computer. Some resistance to micros as fad among faculty.
8. WILLOW GLEN H.S. (San Jose) 1,420 students 25% minority: 19% Hispanic, 4% Asian Middle- to Upper-middle class parents. 80% continue their education.	1982: 3 Apples, 1 Atari, 1 Northstar: Science classes. 1984: 16 Commodore 64s in Computer Center, 1 Apple in Home Economics, 1 Apple in Drafting class, 1 Apple used for Career counseling, 4 Apples in business machine classroom. 1984 Total: 28 micros By 1985 expect 31 Decentralized.	Parents' Club donations. Federal Vocational funds (VEA). Corporate donations. Science contests.	Administrative bookkeeping, programming, science classes, nutrician education, career counseling, drafting, word-processing, computer club, bookkeeping class. School newspaper formatting expected in 1985.	Principal. Strong parental pressure. 8-10 teachers will use computers in class in 1985, of 70-member faculty One teacher released from one class to learn about computers -- elementary level skills.

TABLE 2. Summary (cont.)

High School/ Demographics	Computer Equipment/Location Time of Application	Funding Sources	Major Applications	Innovator(s)/ Process
9. WOODROW WILSON (San Francisco) 1,630 students 92 teachers and administrators 97% minority: 38% black, 23% Asian, 19% Hispanic 17% Filipino. Inner-city community with many recent immigrants.	EDP Center for district with 2 HP-2000 minicomputers, 50 terminals at Wilson. 1982: 1 Apple-on-a-cart, 9 Apple IIe's. 1983: 1 Apple IIe, 1 TRS-80, 1 Dynatel. 1984 Total: 13 micros, 50 terminals. By 1985 expect 23 micros.	Ford Foundation. Cowell Foundation State and Federal funds to inner-city schools. Corporate donations.	Remedial reading and math, ESL, programming (BASIC, PASCAL), word-processing. Secretarial and administrative tasks.	Principal, one teacher. 40/92 teachers trained to use micros. Decreasing teacher resistance to micros.